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MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

6 CC

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. LXXVIII.

EDITED BY

JAMES FORREST, ASSOC. INST. C.E., SECRETARY.

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ERRATA.

Vol. lxxvii., p. 58, line 2 from bottom, *for* "rate," *read* "gate."

" " p. 154. The sentence at the 13th line from bottom should read "True, very high tensions required from the cylinder within the coil very great resistance, &c."

" " p. 305, footnote, *for* "p. 158," *read* "p. 306, line 12."

" " p. 307, lines 6, 24, and 29, *for* "S_1 O_2," *read* "S_l O_2."

" " p. 331, line 1, *for* "precipitant," *read* "precipitate."

" " p. 335, line 1, *for* "concerted," *read* "connected."

" " p. 335, line 19, *for* "0·0044," *read* "0·0004."

" " p. 342, line 2, and p. 344, lines 11 and 19, *for* "Probyn's," *read* "Dixon Provand's."

" " p. 344, line 22, *for* "five," *read* "six."

" " p. 345, line 8, *for* "5 feet 6 inches," *read* "6 feet."

" " p. 345, line 22, *for* "20 lbs.," *read* "30 lbs.; in the fifth 20 lbs."

" " p. 382, line 1, *for* "Pacific and São Francisco," *read* "Recife and São Francisco."

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THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1883-84.—PART IV.

SECT. I.—MINUTES OF PROCEEDINGS.

22 April, 1884.

Sir J. W. BAZALGETTE, C.B., President,
in the Chair.

(*Paper No. 1997.*)

"On the Comparative Merits of Vertical and Horizontal Engines, and on Rotative Beam-Engines for Pumping."

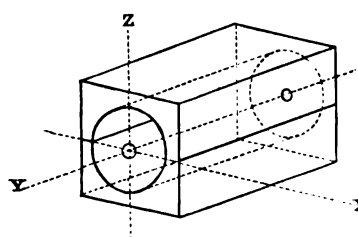
By WILLIAM EDMUND RICH, M. Inst. C.E.

THE primary object of the present Paper is to provoke discussion in this Institution on the comparative merits of vertical and horizontal engines, where large powers are required; and on the advantages which rotative beam engines possess, especially over horizontal engines, for pumping purposes. The Author will further give detailed illustrations and descriptions of various arrangements of beam pumping-engines, constructed in recent years by his firm, with some statistics of their efficiencies and performances.

The Author has for many years laid down for himself the axiomatic principles that, as far as possible—

"No single pair of brasses forming a bearing should be subjected to wear on two or more axes, at right angles to one another;" and "all bearings should be adjustable in the direction in which they wear."

FIG. 1.



Thus, if O Y (Fig. 1) be the central axis of a pair of brasses, divided in halves by the plane X O Y, and O be the origin of co-ordinate planes: then the wear should be as nearly as possible in the direction of the axis O Z,

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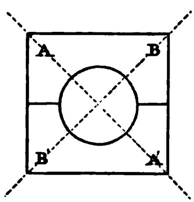
that being the direction in which it is adjustable. The journal in it should be free from pressure, in the direction of the axis O X, as it manifestly cannot be adjusted in that direction, and there are many practical reasons which make it undesirable to apply any material "end-on" pressure, from a collar, in the direction of axis O Y, on the same bearing, which is subject to internal wear.

The best engineering practice shows the general acceptance of these principles, and yet it is extraordinary to see how frequently they are neglected. They were first suggested to the Author by observing the difficulty of keeping inclined engines at right angles to one another, and working on to one crank, free from "knock" on their main bearings.

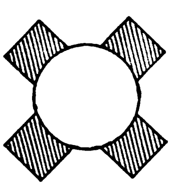
If Fig. 2 represents a main bearing of such an engine, with cylinders in the directions C and D, it is clear that engine C will wear the brasses in the direction B and B′, while engine D will wear them at A and A′, and the combined effect will be to "rimer" out the brasses all round the circle, enlarging their diameter; and no adjustment in one direction only can remedy this. The result is, that they must remain slack at the sides. The only sound remedy, when such an arrangement of engine is adopted, is to divide the brasses into three or four pieces (Fig. 3), and to make the opposite pairs individually adjustable; quadruple brasses are necessarily complicated, and require careful setting up.

FIG. 2.



An instance of wear in the direction of the third axis, would be afforded by taking the thrust of a screw propeller endways, on such a bearing as Fig. 2.

FIG. 3.



Now the horizontal engine affords several examples of wear on two axes, and in directions inconvenient for adjustment. Primarily the main crank-shaft bearing has to withstand the thrust on the connecting-rod nearly horizontally, and the weight of the fly-wheel vertically; possibly also the pull of a driving-belt, or reaction from driving by mill-gearing, in some other direction. In powerful land-engines, it is usual to make such bearings with double inclined brasses, but there is generally some perceptible motion in them; and a better arrangement, were it not for the complication, would be treble brasses, as generally adopted in the best portable-engine practice. Fig. 4 represents a section through Messrs. Clayton and Shuttleworth's ordinary bearing of this class.

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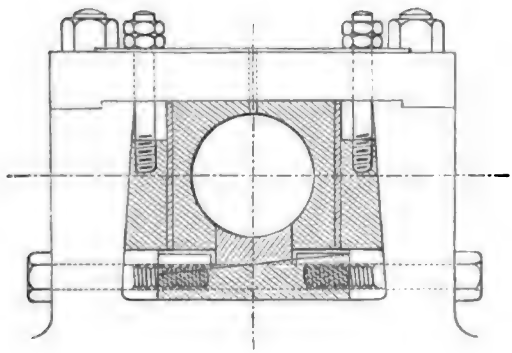
In large horizontal marine-engines where there is no fly-wheel, such bearings are usually in halves, and adjustable horizontally.

The Author regrets to record, that within the last six months, he has seen a powerful new horizontal land-engine exhibited, with the main-bearing brasses in halves divided horizontally, regarding

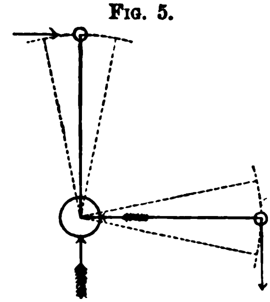
Fig. 4.



which further comment is unnecessary, though similar blunders appear too often, and especially in mill-gearing.

If a horizontal engine is set to work vertical pumps, either its own air-pump, or the service pumps for raising water from a well, it must actuate them either by toothed gearing, or bell-cranks, the latter being the more efficient so far as losses by friction are concerned; but then the above difficulties recur again, as the plummer blocks for the main gudgeon of a bell-crank have to withstand reciprocating wear both vertically and horizontally, as in Fig. 5. In this case the vertical and horizontal forces resolve themselves into a diagonal force, acting nearly in one diagonal plane, so that double inclined brasses will meet the difficulty. If, however, vertical blocks with double brasses only are adopted, as is generally the case, they will surely knock. The public-works contractor, with machinery doing temporary duty, readily tolerates such blemishes, and he can fit new brasses before the machinery is started on its next job; but noisy slack-working machinery is undesirable and unsafe for steady permanent duties, such as waterworks pumping.

Fig. 5.



In horizontal-engines of small power, the reciprocating parts are

of small weight, and there are then several features regarding them, especially if they are simple non-condensing engines, which render them desirable; the chief being, their simplicity, directness of action, and economy in first cost; but these advantages vanish, as the engine increases in size, and has probably to work an air-pump, and perhaps service-pumps. Then a heavy piston has to be dragged backwards and forwards along the cylinder, which can never be very efficiently lubricated, thus absorbing material power in friction; and the first result, if the weight is borne by the bottom of the cylinder, will be to wear both cylinder and piston oval. Thus eventually steam will be wasted, and the economic performances will suffer. At the same time the piston-rod glands will also wear down and become oval. The usual remedy for these defects is to support the piston-rod ends and piston on blocks working in guides, both fore and aft of the cylinder, and these bearing surfaces should be capable of being set up vertically; but then, in very large engines, the piston-rod will bend downwards with the central load of the piston, and will thus neutralize the good done.

So much importance is attached to this point by some Swiss and German engineers, that they actually turn the piston-rod to a curve, so that it will only become straight when the ends are supported by the guide-blocks, and the piston is suspended in the centre; but such refinements have not yet been practised in this country, and those who employ large horizontal-engines have to face the periodical inconvenience of re-boring their cylinders, or they must submit to loss of steam and fuel, through leakage past the piston.

In small engines it is now usual to bolt the cylinder on to the end of the bed-plate, and to let it overhang; the type of bed-plate much in vogue being that introduced into England with the Corliss engine; but with large condensing engines that is scarcely admissible, as the tail-rod above mentioned must be introduced, and probably an air-pump has to be worked in some manner off it. Then the cylinder must be bolted down to a bed-plate beneath it, but in such a manner that it shall be free to expand faster than the bed-plate, as it gets warm.

For efficient condensing, a vertical treble-valve air-pump is always to be preferred, but it can only be worked by a horizontal-engine in some complicated manner, and generally by a bell-crank, which has been shown to be objectionable. A consequence is, that a horizontal double-acting air-pump, worked direct off the piston-rod, prolonged for the purpose, is generally preferred.

Such pumps, if carefully designed, will give a good vacuum, but

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the engine will be liable to accident, if care be not taken in starting it, to prevent too much injection being turned on, and overflowing from the condenser into the cylinder. The Author has known several serious accidents from this cause, as, if the piston makes a bound forward, and then suddenly encounters a block of water in the cylinder, the *vis viva* of the fly-wheel will drive it forward against the obstruction, till something yields, and that may be the cylinder or cover, or perhaps the bed-plate itself.

If a service-pump for waterworks purposes has to be driven, the air-pump must give way to it, and be placed at the other end of the engine, opposite the crank-pin, unless indeed the two pumps and cylinder be placed tandem, in a line one behind the other. Even one pump behind the cylinder very much hampers the freedom for getting at the steam piston, and the difficulties of disconnecting are yet further added to when two pumps are placed in line.

It is desirable, as far as possible, to design all steam-engines with facilities for draining the cylinder, during each exhaust stroke, of any water which has accumulated in it from wet steam admitted, and condensation from radiation and loss of potential heat in consequence of its conversion into work during expansion. Such water, if allowed to remain, not only makes the engine noisy, but it will absorb an immense amount of potential heat from the incoming steam in the next steam-stroke, and thus the economic performances of the engine will be greatly reduced.

Steam-jacketing is of course the best antidote, as it causes the re-evaporation of such water, but all engines are not steam-jacketed; and it is only necessary to watch the working of an un-jacketed horizontal-engine, with the slide-valve on the top of the cylinder, to become convinced of the truth of this view. No engine such as that can work economically, as the clearances at the cylinder ends are always more or less occupied by water, and the drain-cocks in some cases have to be kept open constantly.

An engine with the slide-valve at the side of the cylinder, especially if the exhaust-pipe descends from the exhaust-port, gets rid of the water more freely; and so much consequence is there in this, that in the Corliss engine the exhaust ports with separate valves are invariably placed beneath the cylinder, so as to thoroughly drain it; and Messrs. Donkin, in their horizontal-engines, which have given very high economic performances, generally place the slide-valve chest low down on the side of the cylinder to gain the same object.

It is now almost universally recognised, that to effect economy engines must be on the compound principle; but the inconveniences

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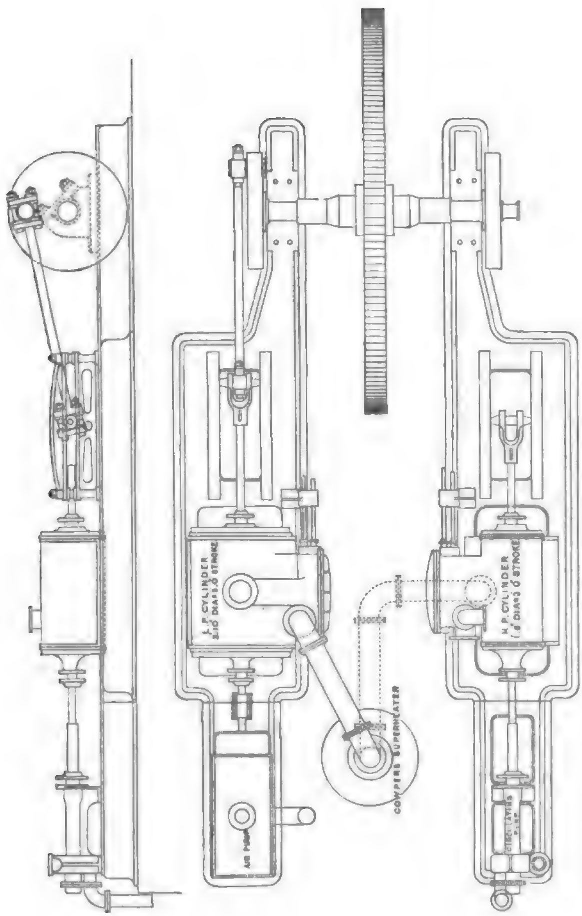
referred to, of disconnecting when two or three pumps or cylinders, are arranged in line with one common rod, rather discourage the adoption of single-crank compound horizontal-engines; and a better arrangement is, to place the cylinders side by side, with

FIG. 6.



Scale $\frac{1}{50}$.

cranks at right angles, as in the engines Fig. 6, constructed by Messrs. Easton and Anderson in 1873, for Messrs. Siemens' works at Charlton. In these engines the main bearing brasses are in halves and inclined, the cylinders are 18 inches and 34 inches in diameter by 3 feet length of stroke, with expansion

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slides and steam-jackets on both cylinders, and air-, feed- and circulating-pumps behind the cylinders. They indicate 180 HP. at forty-five revolutions per minute, with 60 lbs. boiler pressure per square inch, the exhaust steam being condensed in Cochrane evaporative surface-condensers on the roof of the engine-house. Both engines and condensers have worked satisfactorily from the first. Mr. E. A. Cowper, M. Inst. C.E., was consulted regarding several details of the design, and one of his patent superheaters is placed between the cylinders.

In an arrangement of single-crank horizontal compound engines, in favour on the Continent, the two cylinders are placed side by side, and the piston-rods are attached to one cross-head which crosses the engine-bed, and has two side connecting-rods from its ends, to two concentric outside cranks, on the ends of the crank-shaft.

The Author has no experience of the working of engines of this type, but would suspect them of being liable to cross-racking tendencies, unless the cross-head be well guided. If the cross-head be arranged at the end of the cylinders most remote from the crank-shaft, the arrangement presents advantages for working pumps, as the air- and feed-pumps, and one or more service-pumps can easily be worked off it. For such duties it is probably an economical engine in first cost.

An example of a compound horizontal-engine working a large number of pumps, is that made in 1857 by Messrs. Easton and Amos, for the hydraulic ship-lift in the Victoria docks, and an outline of it is shown in Fig. 7. A high-pressure cylinder, 23 inches in diameter, by 24 inches length of stroke, is placed in the centre between two low-pressure cylinders, 32½ inches in diameter, the piston-rods of all being attached to two cross-heads stayed together, from which an air-pump, two feed-pumps, a cold-water pump and twelve hydraulic-pressure pumps are worked. The crank-shaft is fitted with two over-hanging fly-wheels and crank-pins, which are connected with the nearest cross-head by two side-rods.

The largest rotative horizontal-engines constructed in this country for waterworks purposes, within the knowledge of the Author, are those at the Odessa Water Works, by Messrs. Simpson. They are arranged somewhat similarly to Fig. 6, but they are very much larger, having cylinders 30 inches and 54 inches in diameter respectively, and 48 inches length of stroke, and a double-acting pump behind each, 15½ inches in diameter, working against a head of 300 to 350 feet. These engines are probably among the best of their kind, and so far as the Author has heard they have done

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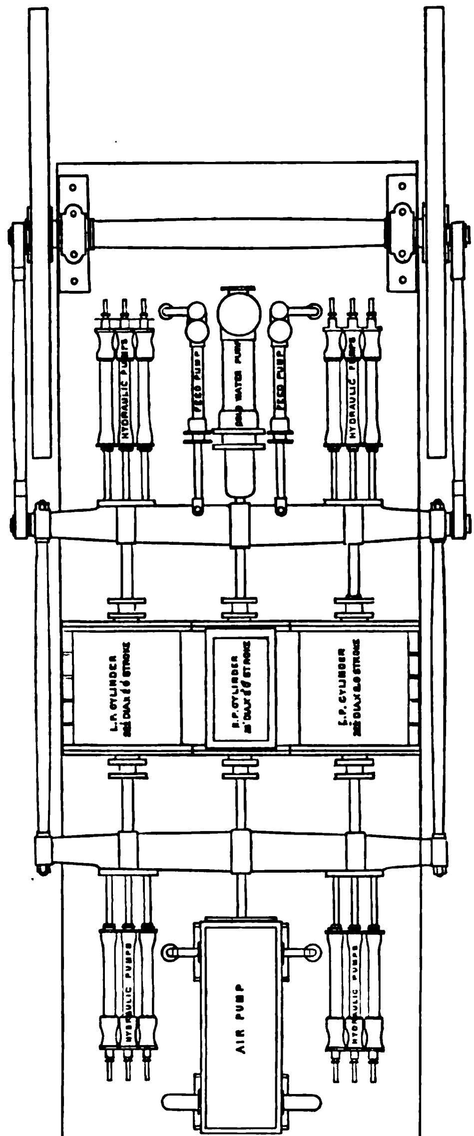
FIG. 7.



Scale ¼ of an inch = 1 foot.

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their duty well; but he would be interested to hear whether in the long run they can compare favourably, in their fuel consumption and cost of repairs, with the best examples of beam-engines.

Horizontal-engines require less head-room than vertical or beam-engines, but those of large power need considerable floor-space, which is often valuable for other purposes in the centre of a factory. Their foundations are frequently as costly as those necessary for self-contained beam-engines of the same power, and vastly more so than those for vertical-engines with inverted cylinders.

Balancing is necessary for horizontal-engines working at high speeds, but it is not easy to balance satisfactorily when single over-hung cranks are adopted.

Now the Author submits that most of the blemishes mentioned are avoided by adopting vertical instead of horizontal engines. Gravity acts in the same direction as the piston-motion, so that there is no sideways wear of consequence on the main crank-shaft bearings, which can therefore be always made in halves, with vertical adjustments only. The pistons and cylinders, though they may wear with continuous working, always tend to preserve their cylindrical shape, and lubrication acts uniformly round the whole circumference. The air-pump can always be worked vertically, either directly or indirectly, by means of levers, and it can be placed at any desired depth below the cylinder. Being vertical, it may be of the treble-valve type, which is more efficient than any double-acting pump.

If the engine is required for mill-purposes, it is easy to make it self-contained on a compact bed-plate, requiring little foundation, or floor-space; and balancing the reactions of the working parts is of much less consequence than in horizontal-engines, as the inertia of the earth neutralizes nearly all vibration in a vertical direction, the amount reflected being of little consequence. To this may be added, that it is easier to keep vertical-engine cylinders free from moisture than those in horizontal-engines.

Many winding-engines are made with the drum keyed direct on to the crank-shaft, which is above the cylinders, with a cylinder on each side of the drum, and a great many powerful drainage engines were made a few years ago, with the crank-shaft similarly placed above the cylinders, notably those at "Schellingwoude," described in Mr. Hayter's Paper on "The Amsterdam Ship Canal,"[1] and those in Mr. Welsh's Paper on the "River Witham Drainage: Pumping Machinery and Works at Lade Bank."[2]

[1] Minutes of Proceedings Inst. C.E., vol. lxii., p. 17. [2] *Ibid.* vol. xxxiv. p. 178.

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It is a growing fashion, and a very good one, in large factories, having several long lengths of shafting, to drive each line separately by one or two small vertical engines of this type, working direct on to it, so that one range can be stopped temporarily, without interfering with any others, and thus all toothed gearing and main driving-belting are avoided.

Vertical marine-engines are almost invariably of the inverted cylinder type.

For blast-furnace air-pumps, one of the most approved arrangements is, to place the pump vertically above the cylinder, with a piston-rod common to both, and the crank-shaft below them.

For working large reciprocating water-pumps, vertical-engines are equally advantageous, and the Author believes they may in future be used more frequently than in the past, for driving pumps direct beneath them; but for such duties there are many practical reasons, which make indirect action through the medium of a beam, specially advantageous.

Primarily the beam-engine permits a long stroke and a high piston-speed to the steam-piston, and at the same time a moderate stroke and a lower speed to the pump or pumps. Secondly, one, two or more pumps, can be placed under the beam and worked conveniently by rods from it. Thirdly, a single beam-engine is very convenient for the introduction of compound-cylinders on the Woolf principle, and a vertical air-pump below the cylinder is easily arranged. Fourthly, the reciprocating parts, are easily balanced, and the "parallel motion," usually adopted for keeping the piston and pump-rods working vertically, moves with much less friction and wear and tear than the cross-head guide-blocks in direct-acting engines of the same power. Fifthly, nearly every bearing in a beam-engine can be adjusted vertically, that being the direction in which it wears. Even for mill purposes, beam-engines are often adopted, in consequence of their great freedom from the necessity of overhauls and repairs.

The question of beam pumping-engine construction, will be further discussed in the sequel, but before doing that, it will be profitable to criticise modern practice generally, in respect to the above questions.

Nearly all the rotative engines of James Watt and his immediate successors were of the beam type, and as an example of their longevity, one of Watt's engines is just now being dismantled, after working for one hundred years, at Messrs. Barclay & Perkins's brewery.

The smaller first cost of direct-acting engines has recently led to

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their almost universal adoption for mill purposes; and those of the horizontal type, being in many respects the cheapest, have been used more generally than vertical-engines.

In the Paris Exhibition of 1878, and in that at Brussels in 1881, the majority of the continental engines were of the single-cylinder horizontal type, fitted with various elaborate detent valve-gears, and frames of the type first introduced in the Corliss engine, with very large crank-journals to withstand the shock of the initial steam-admission.

In Paris there were very few direct-acting vertical-engines; but the Author remembers several beam-engines, two of which came from Rouen, where they are evidently in vogue for mill-driving.

Within the last few months he has seen some very fine specimens of beam-engines in one of the largest cotton-factories in Ghent, so that their virtues are evidently appreciated where they are known. Singularly, however, he does not remember ever seeing a beam-engine of German or Swiss make.

Some of the most powerful horizontal-engines in this country are used for driving roll-trains in iron and steel works; but the Author believes that vertical compound-engines might often be used with greater advantage for such duties. They would be more economical in their steam consumption, they would last longer, and they would occupy much less floor-space than horizontal-engines.

The superiority of the vertical over the horizontal type is preeminently marked in marine-engines, both in their economical performances after continuous working, and their greater freedom from repairs. This has been so generally recognised of late years, that the horizontal-engine has almost vanished from the mail and mercantile navies, and the Royal Navy has adopted vertical-engines in all its recent ironclads, being ready to provide extra belts of armour plates, for surrounding the engine-rooms, in order to get the advantages of better working engines.

Horizontal-engines are now only used in the unarmoured ships, in which it is important to keep them below the water-line. So long as the line-of-battle ships were fitted with horizontal-engines, cracked cylinders were frequent; the pistons, cylinders and glands, in long cruises under steam, wore extravagantly, and the Author believes that no such engines could ever have worked economically after long runs without overhaul. In fact he believes that, apart from the exhaustion of their coal supplies, it would have been well nigh impossible for them to have made the long runs without a single stoppage, which are now recorded almost daily, by the leading lines of mail-steamers.

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The Author hopes he has made his opinions sufficiently clear to those whose views differ from his own to induce them to thoroughly discuss them.

The waste of public money by many petty corporations and local authorities in this country, at the present moment, in purchasing the cheapest machinery, which will rapidly deteriorate, rather than that which will work economically, both as regards its consumption of steam and cost of maintenance through long periods, is enormous; and the sooner the country knows the mature opinions of its engineers on such subjects the better.

A manufacturer in an uncertain trade, whose capital is worth 8 per cent. to him, may act wisely in purchasing a second-rate engine at £2,000, rather than a first-rate one at £3,000, though he may be perfectly cognisant that it will waste £60 worth more fuel, and will cost £20 more for maintenance and repairs than the better engine per annum. He would not be a loser in consequence, and he risks £1,000 less capital in his business; but the public authority, which can borrow money for executing its permanent works at 4 per cent., would be a loser of £40 a year if it elected to purchase the cheaper engine.

A horizontal-engine in its crudest form is no doubt the cheapest in first cost, but if it is condensing, and is fitted with quadruple or triple main-bearing brasses, and a tail-rod with adjustable blocks on guides for supporting the piston, it becomes as dear as a vertical-engine and is not so enduring; and if in addition to these refinements, it is to be compound, and arranged for working pumps in a well, the cost of it, with its buildings and boilers, will be very nearly if not quite as much as a Woolf beam-engine with similar belongings, and the maintenance of it will cost twice as much.

The question is: "Are the modern continental engineers right in adopting horizontal-engines for nearly all land purposes? or is the Author right, in advocating a much larger use than hitherto of vertical-engines for land purposes, and using them almost invariably where large pumping power is required?"

Beam-Engines.—Passing now to the question of beam-engines for pumping, the aim of the Author's firm during the last fifteen years has been to make a beam-engine as far as possible self-contained on a massive cellular bed-plate, cast in one piece, and to carry the cylinders, valve-gear, main-bearing, beam-carriages, and engine-entablature, entirely on this foundation-casting, so as to leave the whole engine nearly or entirely free from the engine-house walls, which can then be of much lighter construction than is necessary when the entablatures are supported by them. The

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bed-plate also takes the place of the expensive ashlar work, usual in most engine foundations, as it binds the whole machine together, and requires only to be bolted down to simple brick-in-cement piers, the joint between the bottom of the casting, and the brick-work, being made with grout, after the top planed surface of the plate has been properly levelled and centred.

Where shallow pumps are required, it is frequently possible to place them in gaps left in the brick foundations, and to bolt them direct to the underside of the bed-plate, as in the Lambeth Water-works engines at Brixton Hill, Plate 1; while for working deep well-pumps the bed-plate usually spans the well. The general effect of the self-contained principle in this case is to add to the cost of the engine proper, but to reduce the cost of the engine-house and foundations to a greater extent, so that the total cost of a pumping-station, including its machinery, is reduced by adopting it.

The earlier engines of this type were made with six columns, as in Fig. 17. These supported the entablature to which the beam-carriages were bolted. But the thrust of the connecting-rod under heavy strains caused some motion endways on the entablatures so supported. Accordingly ornamental open-work A frames were substituted for the centre columns, as in Plates 1 and 3. In these cases the beam-carriages were bolted and keyed to the entablature, which was again bolted to the A frames and columns, and the main crank-shaft plummer-block was bolted to the bed-plate as in Plate 1. But the tendency is to increase the sizes of castings, so as to reduce the number of machine joints, subjected to important strains, as much as possible. Thus, in all the more recent examples, the main-bearing has been cast solid on the bed-plate, and the A frames have been extended upwards to include the beam-carriages, at their top ends, as in Plate 2. At the same time, the bed-plates and A frames have, in several recent engines, been made as cellular box castings, an arrangement which adds very much to their stiffness. The cylinders are bolted direct to the bed-plate, which is planed over its top surface, and in all first-class engines they are steam-jacketed all over, and lagged with felt and mahogany. In many instances the steam-jackets have been formed by bolting loose liners of special close-grained metal into the main-cylinder castings; but the bottom joint of the liner in small engines is rather inaccessible, and so much difficulty has been experienced in keeping the top joint, in which some freedom is allowed, steam-tight, that it has been found preferable recently to cast the liners in the main cylinder castings.

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In all large single-engines the Woolf compound principle is adopted, the low-pressure cylinder being usually from three and a half to four times the capacity of the high-pressure cylinder. The standard steam-pressure adopted for twenty years past has been 60 lbs. per square inch; but with the introduction of steel plates in boilers, of about the same scantlings as the iron ones, the safety-valve pressure has latterly been increased in many instances to 75 lbs. above the atmosphere. The Author believes that there is no appreciable gain in expanding more than eight to ten times with 60 lbs. steam, and ten to twelve times with 75 lbs. steam-pressure; and he has seen many instances in which the above capacity-ratios between the high- and low-pressure cylinders might be reduced somewhat with advantage, as piston-friction and leakage leave little gain in useful power, derivable from the very attenuated low-pressure cylinder diagrams too often seen, over the fuller diagrams which would have been given by a smaller cylinder. This is especially noticeable in compound-engines, with cylinders not steam-jacketed. In such engines, working at a low speed, water is always present in the low-pressure cylinder, at a temperature considerably below that of the steam exhausted by the high-pressure cylinder. The result is, that so much steam is condensed by this water, and the cold cylinder-walls, on its first admission, as to make an enormous fall between the final pressure in the high-pressure cylinder and the initial in the low-pressure cylinder; and at the same time the low-pressure diagrams are greatly reduced in their dimensions, sometimes to so large an extent as to become almost worthless. An example of such a diagram is given in Fig. 8.

In experiments on an engine of this kind in 1877, the Author found that, unless special arrangements are made for removing this water, the low-pressure cylinder itself, and the water within it, will frequently remain comparatively cold for hours after the engine has been started; and even when an escape-valve is provided for removing the water, such a cylinder only warms up slowly in the first place. In the engine which he tested, he found that at one hour thirty minutes after starting, the water in the cylinder top, when steam was being admitted, had only a temperature of 150°; at two hours fifteen minutes, it was 155°; at three hours five minutes, it was 175°; at four hours fifty-five minutes, it was 192°; but having once gained such a temperature as the last-named, its further advance was very rapid, if the escape-valve remained open, and the engine appeared suddenly to work more freely, and to be capable of developing considerably more power than before. For instance,

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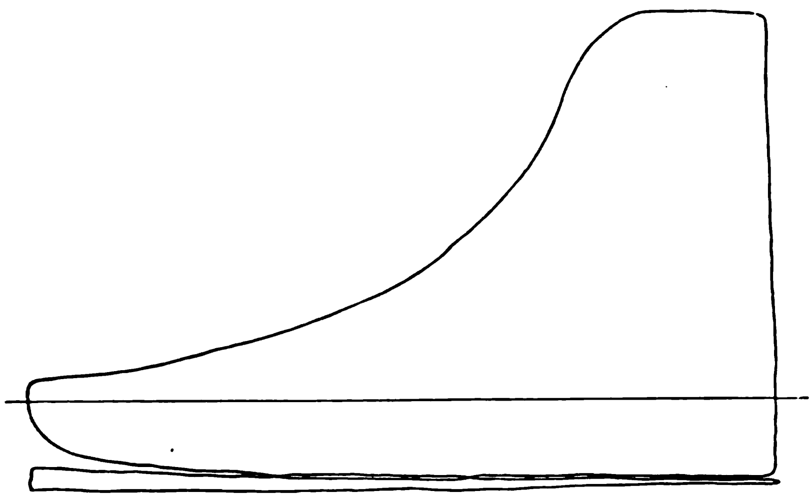
the escape-valve fitted to the top of the low-pressure cylinder was opened to discharge the water above the piston, on one occasion, when the temperature of that water was 187°; two minutes later its temperature was 198°; three minutes later, 204°. Twelve minutes after the valve had been shut off the temperature had fallen to 185°; but in two minutes after opening, it rose to 202°. A diagram, Fig. 9, was taken off the engine two hours after starting, when the temperature of the water in the cylinder was 150°, and a diagram, Fig. 10, five hours after starting, when it had risen to above 200°. In the first case the low-pressure cylinder shows a mean indicated pressure of only 4·43 lbs. per square inch, and

Fig. 8.



it does only 24 per cent. of the whole work of the engine; while in the second case, it indicates 8·32 lbs. per square inch, and does 41 per cent. of the whole work of the engine.

The Author's firm had adopted steam-jackets largely previously; but these experiments so thoroughly convinced them of the great importance of having steam-jackets in all cases on both cylinders, that they have since made no large compound-engines without them.

The difficulty in getting rid of the water above the piston, in the case mentioned, suggested to the Author the propriety of putting an escape-valve opening downwards through the piston itself; and he would have fitted one if he could have made it

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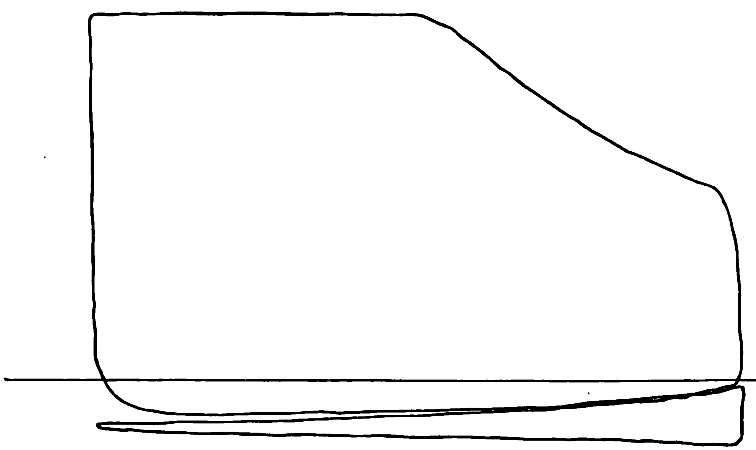
easily accessible. He was much interested in hearing recently that such valves have in many instances been so fitted with advantage.

When compound-cylinders are not steam-jacketed, the Author believes economy will result from admitting some live steam to the low-pressure steam-chest for at least an hour or two after starting an engine.

There is a considerable variety of opinions as to the best type of valves and valve-gear to be adopted in beam-engines. In all those under review, short D slide-valves have been adopted, and in most of the recent examples the high-pressure cylinder has

Fig. 9.



been fitted with expansion-slides of the Meyer type, working on the back of the main valve, and adjustable by hand while working. The main-slides of both cylinders are driven by one eccentric, and the expansion-slides either by an eccentric, or by a lever from a gudgeon on the beam, which is a very favourable arrangement.

When the high- and low-pressure cylinders work on to separate cranks at right angles to one another, and each has its own pump, as in the Lambeth Waterworks, Brixton Hill, Plate 1, it is necessary to fit adjustable expansion-slides to the low-pressure cylinder also, to enable the work done by the two engines to be equalized. It is a singular, though a necessary, consequence of this arrangement, that the earlier the cut-off is in the low-

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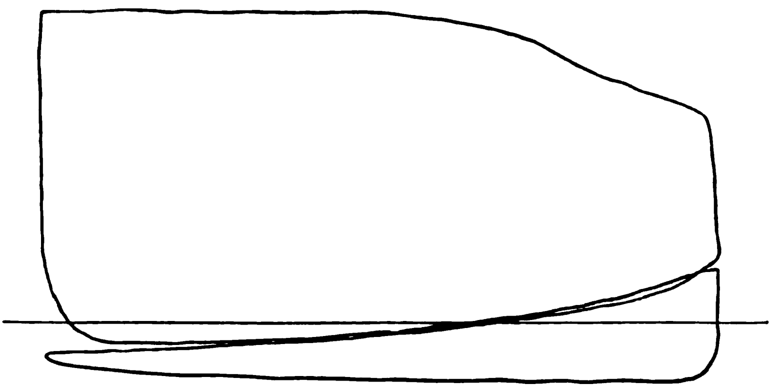
pressure cylinder the larger is the proportion of the work done by it.

The chief objection to most variable expansion-gears, in rotative-engines is, that owing to the obliquity of the connecting-rod, the "cut-offs" at the top and bottom of a cylinder, are only uniform for one grade of expansion, and they become very dissimilar for grades far removed from that at which they are the same. Thus, suppose a beam-engine, such as at the Buenos

Fig. 10.



Ayres sewage works, Plate 2, with a stroke of 72 inches, to be fitted with ordinary Meyer valves, which are set to cut off uniformly on the up and down strokes, at half-stroke, or 36 inches, then they will require considerable care, in design and setting, to get such favourable results as the following, viz.:—

				Inches.			Inches.	
Actual cut-off for a mean cut-off at .	$\frac{2}{10}$	stroke	=	13·5	on down stroke	and	15·3	on up stroke.
„ „	$\frac{3}{10}$	„	=	21·0	„	„	22·0	„
„ „	$\frac{7}{10}$	„	=	52·0	„	„	49·0	„

Such variations of power, on the up and down strokes of an engine, impair its steady speed of rotation, and prevent its working at very low speeds.

To get over the difficulty, the Author has recently introduced the expedient of putting screws and nuts of dissimilar pitch, to the two plates of the Meyer valve, so proportioned that they very nearly neutralize the above irregularities.

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The Buenos Ayres engines, Plate 2, are fitted with these valves, and they give—

For	$\frac{2}{10}$	mean cut-off	14·4	inches	on down,	14·1	inches	on up stroke.
„	$\frac{3}{10}$	„	21·6	„	„	21·5	„	„
„	$\frac{5}{10}$	„	36·0	„	„	36·0	„	„
„	$\frac{7}{10}$	„	50·4	„	„	50·7	„	„

Most of the engines illustrated in this Paper are fitted with a governor actuating an ordinary balanced throttle-valve.

The Brighton and the Portsmouth engines, Figs. 13 and 14, are fitted with air-governors; but they are so delicate and rapid in their action, that they frequently throttle a slow-moving engine to a very different extent on the up and down strokes, and occasionally a fly gets caught in the air inlet, and stops the engine.

Latterly, the Porter or other high-speed governor has been adopted, and in some instances, for large pumping-stations, where an attendant is always at hand to shut off steam quickly in case of an accident, the governor has been suppressed as many engineers consider it an unnecessary complication in such cases.

If the governor, with its throttle-valve, or other regulating gear, could be absolutely relied on to be in proper order whenever an emergency occurred, it would be wrong to be without one in any case. But there is a tendency to disregard things not generally useful, and when the emergency does arise, the throttle-valve may be either stuck fast or so badly adjusted that it may not nearly close when the governor is full up, and so allow the engine to race without check, when the resistance is suddenly reduced, as in the case of a burst main near the engine-house.

The adjustment of a throttle-valve governor, is a matter of no mean importance; but it is too often neglected and left to an illiterate mechanic, and probably many an engine has been considered too weak for its work, and another substituted, because the throttle-valve was so adjusted as to be nearly closed when the governor was down. Some enthusiasts advocate the regulation of the expansion in a pumping-engine by the governor, as is so largely practised now-a-days in mill-engines; but this method is necessarily complicated; it is not always reliable, and it is generally superfluous when the power required is so uniform, as it is in most pumping-engines.

When an engine pumps through a long main into a distant reservoir, if the attendant will only keep a steady steam-pressure and the stop-valve wide open, and regulate the engine by the expansion-gear alone, the friction of the main, and the grade of

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opening of the injection-cock, will govern the engine-speed with great accuracy; while if the main serves also as a service-pipe, the same arrangements will allow the speed to vary, so as to maintain a constant pressure in it.

The water-pumping engines at Antwerp, and the pneumatic-despatch air-pumping engines at the General Post-office, are all worked in this way. In the former a steady water-pressure is maintained in the main 12 miles long, which supplies the town direct, while in the latter a steady air-pressure is kept up, the speeds varying constantly to meet the demands, and the governors *only* coming into action when the limiting speeds allowable are reached.

Engine-beams.—The Hartley Colliery catastrophe in 1862, which was caused by the breaking of a large cast-iron engine-beam, led to a general outcry against cast-iron working parts in engine construction, and for fifteen years from that date the Author's firm constructed all their engine-beams of wrought iron, sometimes of two thick rolled plates with cast-iron distance blocks riveted between them, and at other times built up of thinner plates riveted together.

Some English engineers build up their beams of lattice work, and the Cockerill Co. at Seraing, in Belgium, frequently makes them of a cellular box-girder section, riveted up with plates and angle irons. It has been found, however, that beams built up of many parts riveted together are much more costly than cast-iron beams of the same strength, and in some respects they are less satisfactory, as with the severe alternating strains in opposite directions which they have to endure, and with the jarring on them, when loose bearings are tolerated, they are liable to loose gudgeons, and not unfrequently some permanent set is noticed in such beams transversely, after they have been in operation for a few weeks, probably from a slight yielding of the soft plates and riveting.

These experiences, together with the absence of any well authenticated case of failure of a cast-iron beam fairly proportioned for its work, have led to the re-adoption of cast-iron beams in recent practice. They are made sometimes with double flitches cast separately, but more frequently in one single flitch casting, which the Author considers preferable, as no two castings made at different times are homogeneous, and the difference of elasticity in two flitches may be prejudicial to the combined structure. They consist of a mixture of very tough metal, namely, one-third No. 3 Calder Pig, one-third good cast-iron scrap, and one-third Landore Siemens steel-plate clippings from the boiler yard.

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The same kind of metal has been used with great advantage for three-throw pump-cranks, and other structures in which special strength and toughness are desired. Some sample test-bars, 2 inches deep, 1 inch wide, and 36 inches long between supports, recently tested by Mr. Kirkaldy, broke with an average load of 38·3 cwt., and a model engine-beam of the metal, tested against a similar one of ordinary cast-iron, loaded transversely, showed 65 per cent. superior strength, and 54 per cent. greater ultimate deflection.

The Fly-wheel in rotative pumping-engines need not be of the great weight sometimes advocated. If an engine have one cylinder only, working very expansively, or if the work done on the pistons be very dissimilar on the up and down strokes, in consequence of defective valve setting, or if the work to be done in pumping on the up and down strokes be very different, or, finally, if the engine be imperfectly balanced, there will certainly be a need for a fly-wheel possessing sufficient *vis viva* at the lowest desirable speed of the engine, to take up the excess work in one stroke, and to give it out in the next, without material change in the speed of rotation. But it is highly desirable in every beam-engine that it should be well balanced, and that the work indicated and work to be done should bear the same proportion to one another in the successive strokes. The four single beam-engines, by Messrs. James Watt and Co., at the Chelsea sewage pumping-station, are evidently examples of excellent balancing, as they are capable of creeping round steadily at extremely low speeds. Under these circumstances, a fly-wheel of a very moderate weight is in most cases preferable to a heavy one, as the slight reduction in its speed, when turning the centres, will facilitate the gentle opening and closing of the pump-valves, and will thus gain one of the advantages which the Cornish engine possesses.

Size of Engines.—The Author considers that in large waterworks it is better to have several engines of moderate size than a few of colossal proportions. The machinery and buildings need not cost any more in the former than in the latter case, and the working parts of the smaller engines are much more easily overhauled.

The Lambeth Waterworks Company has eight engines, and the Chelsea Company six engines, all of the same size, namely, 150 HP. each for their high service work at Thames Ditton. All of these have been constructed by Messrs. Simpson, and the four engines at the Brighton Waterworks by Messrs. Easton and Anderson have similar cylinder dimensions. Each of those

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several works might have been served by fewer engines of larger size, but there are many advantages and greater security against inconvenience from breakdowns when the engine-power is well subdivided. When engines of larger power are required, it is better to link two together on to one crank-shaft, with cranks at right angles, as shown in Plates 1 and 2. Then very great steadiness of rotation may be obtained with very little fly-wheel, and the engines can be worked if desired at very low speeds.

Speed of Beam-Engines.—If they are well balanced, and fitted with working parts not unnecessarily heavy, and last, but not least, are furnished with pumps having plenty of valve-area, without much lift of valves, and suitable air-vessel capacity, there is no reason why higher speeds should not be run than have been usual.

The inertia of the great weight and length of pump-rods, when an engine drives deep-well pumps, reduces the speed materially below that which it would work at satisfactorily with pumps near the surface. Practically the pumps and their valves limit the speeds; and other things being equal, the nearer they are to the surface, the shorter their stroke, and the larger the valve-area, the faster the engine may run. The Brighton engines, with deep-well pumps, work steadily up to 14 revolutions per minute; the Winchester engine, with similar pumps of smaller size (Fig. 18), at 24. The normal speed of the Lambeth, Antwerp, and Sutton engines is 22 revolutions, but they might all be worked faster. The two earliest Portsmouth engines (Figs. 13 and 14) have worked for twenty-five years at 22 revolutions, and latterly their speed has been increased to 26 revolutions without impairing their steadiness.

Mechanical Efficiency.—It is not only necessary that engines should be economical in their steam-consumption per indicated HP., but it is equally important that as much as possible of the power indicated in the cylinder should be utilized for useful work. This can best be done by conveying the power from the piston-rod to the pump-rod as directly as possible, avoiding all unnecessary friction.

In most cases, when one pump only is to be driven, it is usual to place it on the crank side of the beam centre; consequently the whole of the power necessary for working it has to be transmitted through the beam and main-beam gudgeon-bearings, thus increasing the strains, and absorbing valuable power in friction, which might have been disposed of for useful work, before arriving

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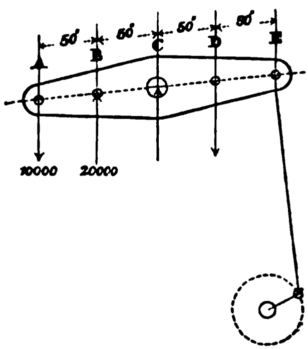
so far. For example, suppose A B C D E, Fig. 11, represents a single-cylinder engine-beam, 200 inches long, with equidistant gudgeons at the points indicated, and steam-cylinder beneath A, crank beneath E, and main beam centre at C, and it is optional to place a double-acting pump with a mean resistance of 20,000 lbs. either at B or D. If it be placed at D, more than 10,000 lbs. effort will be required at A, and the beam gudgeon-bearings must be loaded at C with more than 30,000 lbs., and the bending moment on the beam at C will be 10,000 × 100 = 1 million inch-lbs. While if the pump be placed at B, the load at C will be little more than 10,000 lbs., or about one-third of its former amount, and the transverse bending moment at the beam centre, due to the steam, will be "nil." Undoubtedly the beam must be strong enough to withstand the shock of the steam at its first admission on to the piston at the turn of the stroke, and to transmit a great part of it to the connecting-rod and crank; but the fact remains, that in the second case above cited, very little of the total work done passes the centre, and the beam scantlings may at least be reduced somewhat in consequence. It is easy to balance the weights of working parts on each side of the beam centre, so as to enable this arrangement to be carried out; and Plates 1 and 2 show instances of pumping engines which have the advantage of it.

FIG. 11.



The Lambeth Waterworks engines at Brixton work with the very high mechanical efficiency of 89 to 92 per cent. The Author believes this has been rarely exceeded in rotative pumping-engines, and he traces this high coefficient to the arrangement above described, and to the lightness of the working parts resulting from it. The South Essex Waterworks engine, however, with two double-acting pumps, one on each side of the beam centre, and near the surface, which is an equally favourable arrangement, has also shown over 90 per cent. efficiency.

In the Doncaster engine, Fig. 17, with a double-acting pump on the crank side, the efficiency, or ratio of work done in water raised, as actually measured into the reservoir, was 86 per cent. of the indicated work; while in one of the Brighton engines, with

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two double-acting pumps at the surface and two deep-well lift-pumps, having heavy rods and buckets, adding greatly to the load on the beam-gudgeons, the useful work in water lifted, as measured into the reservoirs, has been found to be 81 per cent. of the indicated work in the cylinders.

When the pump is placed at the cylinder side of the crank centre, it is generally worked off the same parallel motion as that which guides the piston-rods.

A further advance in the direction of relieving the beam and its gudgeons of all unnecessary loads and friction is to prolong one of the steam piston-rods (preferably that in the high-pressure cylinder) through the bottom cover, to work a pump placed beneath it. One of the lift-pumps in the Buenos Ayres sewage-engines is so placed. An objection to this position for a pump is that it is less accessible and convenient for disconnecting; but, with a little care in design, this objection can be easily got over.

There is no doubt that very tight pistons, pump-buckets, and stuffing-boxes often materially impair the efficiency of an engine. As an instance, it may be noticed that one of the Lambeth engines, for a few days after it was first started, showed an efficiency of only 0·80, or thereabouts, but with continuous working it soon improved to 0·90.

Pumps and Air-Vessels.—The question of pumps and their valves is most important, which it is hoped may be brought forward and fully discussed ere long. Time will not allow of its being entered upon in the present Paper; but a few words on the arrangement of pumps may be opportune, as on it should depend the volume of the air-vessels and the permissible speed of the engines.

Fig. 12 shows graphically the variation in the discharge of different types of reciprocating pumps worked by rotative engines. The length of each figure represents 1 revolution of the shaft, which works coincidently with the pump or set of pumps, in each case supposed to discharge 100 gallons in 1 complete revolution. The horizontal line XX shows this mean discharge, and the curved lines above and below the mean show the variations of the flow at different parts of the revolution.

Diagram 1 is of a single-acting pump discharging on one stroke only. If it discharges into an open stand-pipe or air-vessel of infinite capacity, at the near end of a long main, in which a steady flow has to be kept up, this pump in its lifting stroke will force 45 gallons (represented by the shaded part below XX) directly into the main, while the surplus 55 gallons (represented by the shaded curve A above XX) will accumulate in the air-

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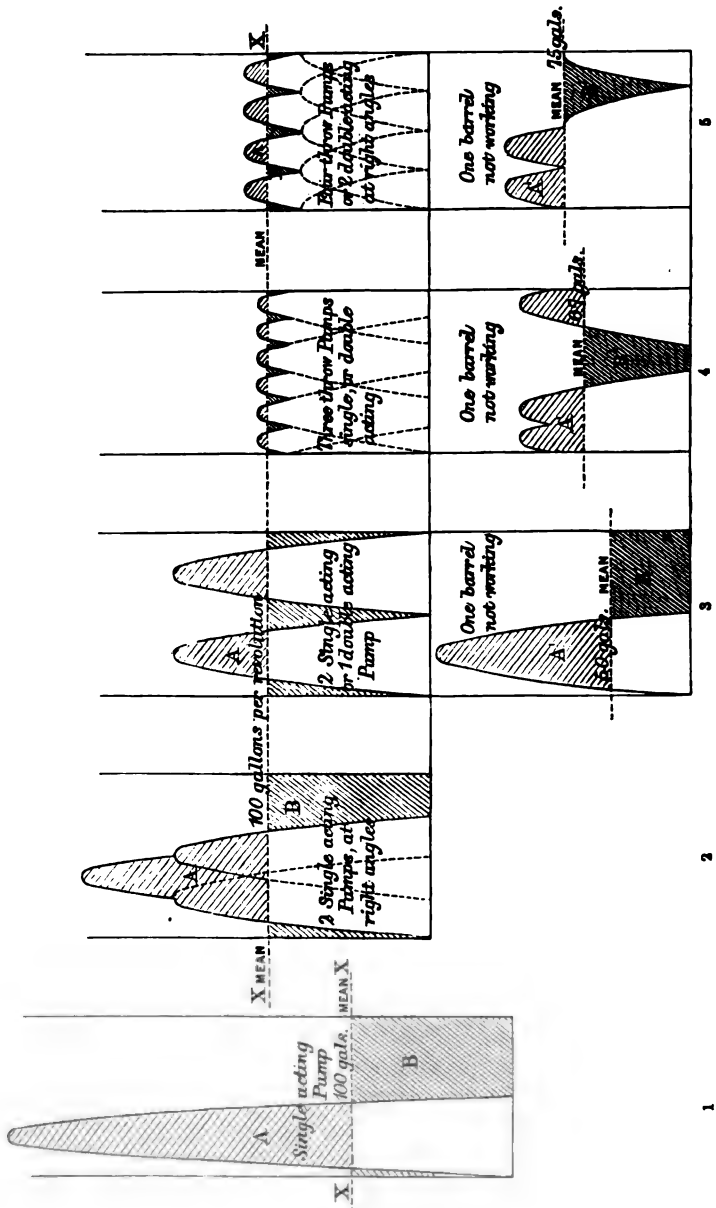
FIG. 12.

VARIATION IN DISCHARGE OF RECIPROCATING PUMPS WORKED BY ROTATIVE ENGINES.



vessel or stand-pipe during that stroke, and will flow on into the main to keep up the steady flow therein, during all parts of the revolution, in which the actual rate of discharge falls below the mean rate. In this case the air-vessel will be thus discharging into the main during rather more than one-half of the revolution, as represented by the area B below the mean line XX.

Diagram 2 represents the discharge of two single-acting pumps, worked by cranks at right angles. In this case, during the second $\frac{1}{4}$ of the revolution, both pumps are lifting simultaneously; so, while that is taking place, the ordinate of one curve must be added above that of the other curve, thus forming the supplementary ridge above them. During the last $\frac{1}{4}$ revolution neither of the pumps is discharging. In this arrangement of pumps the curve A above the mean line represents an excess of 35 gallons forced into the air-vessel.

Diagram 3 shows the curves of two single-acting pumps, worked by a rocking-beam or opposite cranks, or a double-acting pump, and the excess A of one pump is equal to 10·5 gallons. It is easy to see, in this and the following figures, that the volumes of the hillocks A A above the mean line are just sufficient to fill in the valleys B B below the mean.

In Diagram 4, representing the discharge of three-throw pumps, there are two pumps discharging simultaneously during one-half of the whole revolution, so their curves must be compounded as before, and the result is a series of six equal undulations, with an excess A in each of 0·58 gallon only.

It may be shown similarly that a set of double-acting three-throw pumps and six-throw pumps give identically the same diagram as single-acting three-throw pumps.

Diagram 5 is the diagram of four single-acting pumps, with cranks at equal angles, or two double-acting pumps with cranks at right angles, and though not quite so steady as that for treble-barrelled pumps, it is a very satisfactory figure; and it is easily obtained by coupling two engines, each working a double-acting pump, as in Plate 1. The excess A in this case represents 1·05 gallon. Similarly it may be shown that a set of five-throw pumps, either single or double acting, gives results somewhat similar to three-throw pumps, but rather better, namely, an excess A of only 0·13 gallon, with ten uniform pulsations.

From the above diagrams and curves, the Author has calculated the effective air-volumes which should be provided in air-vessels for the several types of pumps considered, on the assumption that the air-volume and the internal pressure in the air-vessel should

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never vary more than 2½ per cent., and that the mean discharge is 100 gallons per revolution in each case. Thus it appears that the effective air-vessel capacity for the

	Gallons.
Single-acting pump should be	2,200
Two single-acting pumps with cranks at right angles .	1,400
" " " " opposite "	420
Three-throw single- or double-acting pumps	23
Four- " pumps, or two double-acting at right angles	42
Five- " single- or double-acting	5·2

The practical result is that 23 gallons of air-volume for the three-throw pumps, or 42 gallons in the four-throw, are as effective as 2,200 gallons in the single-acting pump.

It would be well if such principles as these were regarded in designing air-vessels, as their capacities are now too often determined without any sound reason, and many are too small for their duties.

The only tangible reason for making the air-vessels of multiple-barrelled pumps larger is the possibility of one barrel sometimes failing to act, and there are occasions when, in the absence of duplicate machinery, it may be convenient to work them for a time in this imperfect condition. Under such circumstances the main would suffer if a larger air-vessel were not introduced, but a very much smaller proportion than forty times the water displaced should be sufficient for the air-vessel volume, to provide for such abnormal contingencies; and twenty times that volume, after making fresh curves for the reduced mean flow, with one barrel thrown off, should then be an ample allowance.

Revising the above calculations to meet these conditions, it appears that—

		Gallons.	
Two single-acting pumps at opposite angles	will require	550	of air-vessel capacity.
Three-throw	"	360	" "
Four-throw or two double-acting pumps at right angles	"	250	" "

The diagram shows these abnormal curves below the others with shaded areas A′ and B′, indicative of the variations above and below the mean flow, when one barrel is not working. These curves demonstrate the advantages which three-throw pumps possess in the very steady streams of flow, both in their suction- and delivery-pipes; and experience has long shown how satisfactorily they work, especially when they are connected with long and undulating mains. As a rule they are necessarily driven indirect by gearing; but the Author has long been watching for

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a favourable opportunity of arranging large vertical-engines of this type, to work three-throw service-pumps beneath them direct, as this arrangement would give perfect balancing, minimum friction, and in large engines moderate first cost; and he is glad to learn that the Chester Hydraulic Company is using such engines for hydraulic pumping. It is well to bear in mind that air-vessels are quite as much required on suction- as on delivery-pipes, if they have any appreciable length. An open-topped stand-pipe is most advantageous when it is admissible, as it constitutes an air-vessel of infinite capacity. The Author, in 1872, found that a horizontal double-acting pump, with a suction-pipe about 40 feet long, not furnished with an air-vessel, discharged 15 per cent. more than its full capacity with each revolution, the reason being probably that the column of water in the suction-pipe did not come to rest, but passed on through the pump-valves, till an appreciable time after the piston had started on the back stroke, and then the suction-valves closed with a bang. The pump was 12 inches bore, and 4 feet length of stroke, and worked at thirteen revolutions per minute.

Ornamentation of Machinery and accessibility of all its joints and working parts.—The Author holds the opinion, that the appearance of machinery is impaired rather than improved by the introduction of special ornamentation in the shape of fluted columns, mouldings, and architectural features, borrowed from classical structures of wood and stone. Symmetry, directness of action, and such curved outlines as are necessary for giving uniformity of strength, and conveying the impression of stability, together with good castings and excellence of workmanship generally, are the greatest elements of beauty in machinery. Ornamental mouldings add to the work of the pattern-maker and moulder, they frequently hamper the arrangements for connecting the elementary pieces of machinery together, and they sometimes impair strength by sudden changes of section and sharp re-entering angles, which are always objectionable in metal structures subjected to strain, and sometimes lead to fractures during cooling. No working part should be hidden that can be exposed. On the contrary, the more prominent and accessible it is the better. There is also no reason for hiding or disguising any element of construction or joint; or the bolts, nuts, or keys, which form the attachments. There is no disgrace belonging to any such details, and free access to them all will facilitate erection in the first place, and may be of great importance by keeping them under constant supervision afterwards. There were plenty of highly burnished and ornamental foreign

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machines, and one silver-plated locomotive, in the Paris Exhibition of 1878, but nothing surpassed the dignity of Penn's engines and the best English machine-tools, which were totally devoid of ornament or burnish. If decoration is desired, it is better to bestow it on the engine-house, which is essentially a different structure to the machinery within it, so that marked contrasts are quite permissible.

The Author admires a well-designed engine-house, and thinks the architect might with advantage be called in more frequently to assist the engineer in designing such structures, and the chimneys alongside them; but it should always be borne in mind that the first consideration at every pumping-station should be its machinery, and if moderate first cost is of much consequence, it is better to have an undecorated engine-house, and high class machinery which will work with high economies within it, than to limit the perfections of the engines in order to get the means for ornamenting the shell which encloses them. A sound engine- and boiler-house, with foundations and chimney, can be built for one-third the cost of the machinery and boilers. It is therefore unreasonable to let the buildings cost as much or more than their contents, though such experiences are frequently met with.

The margin of safety in the working parts of the recent engines described in the sequel is 8 to 10. In other words, the working strain on any part is limited to one-eighth or one-tenth of its ultimate breaking strength. An example of the severe strains which such machinery is sometimes liable to was experienced in one pair of the Lambeth Waterworks engines, when they were started on one occasion with a cock in the main closed against them. After some hesitation they started, but within a few seconds they burst the main in three places, but sustained no injury themselves.

Examples of Beam-Engines.—To further illustrate the principles and experiences referred to, the Author exhibits some out-lines and arrangements of various beam-engines constructed by Messrs. Easton and Anderson and their predecessors, and the following are the leading features of them :—

The Brighton Waterworks have four engines. They are all of the same pattern so far as framings, cylinders, and centres are concerned, though they were constructed at various dates, the first in 1854, and the last in 1874. In each a bed-frame in several pieces, bolted together, underlies the whole at the floor-line ; two heavy fluted columns stand on this, and support the entablature-beam, which spans the engine-room, and is built securely into its

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side walls, which thus take up all transverse strains due to the thrust of the connecting-rod and the beam. The high-pressure cylinder in each engine is 28 inches in diameter by 5 feet 4¾ inches length of stroke, and the low-pressure is 46 inches in diameter by 8 feet length of stroke. Steam-jackets were little used when the earlier engines were erected, and they were made without them. For the sake of uniformity, the last was made like the first, but this is now to be regretted, and it is to be hoped that steam-jacketed cylinders, with expansion-valves, may be substituted for the old cylinders in all these engines before many years are over. Recent experience has shown the great saving of fuel that would result from such a change; and the introduction of boilers throughout capable of working with 60 or 75 lbs. steam-pressure would yet further increase the economy.

Each engine spans an oval well, containing two lift-pumps, 32½ inches in diameter, having 30 inches length of stroke, which discharge into the low-service reservoirs at ground level, close to the two engine-houses, and at the surface. A double-acting pump under the beam sucks from this low-service reservoir and pumps into the high-service, while another pump or set of pumps at the outer end of the crank-shaft delivers into the middle-service. Thus one engine suffices for pumping simultaneously into the three zones of supply into which the Brighton Waterworks system is divided.

The third engine, erected in 1867, was tested by the Author five years later, when it had been working for a considerable time without material overhaul. The leading results were :—

Duration of trial	10 hours 35 minutes
Equivalent evaporation from and at 212° per lb. of coal	10·7 lbs.
Mean steam-pressure in boilers	44 „
„ weight of Newcastle coal per I.HP. per hour	3·02 „
„ „ „ steam „ „ „	28·8 „
Average speed in revolutions per minute . . .	13·56
„ I.HP.	204·1
Efficiency or $\frac{\text{useful HP. in water lifted}}{\text{I.HP.}}$ = . .	0·806

The fourth engine, which is fitted with expansion-gear, and is supplied with steam at a higher pressure, was first tested on the 2nd of November, 1877, and then, with an average steam boiler-pressure of 63 lbs. per square inch, gave steam consumption per indicated HP. per hour 23·8 lbs. weight. On the 13th of the same month, a second trial of longer duration was conducted, after

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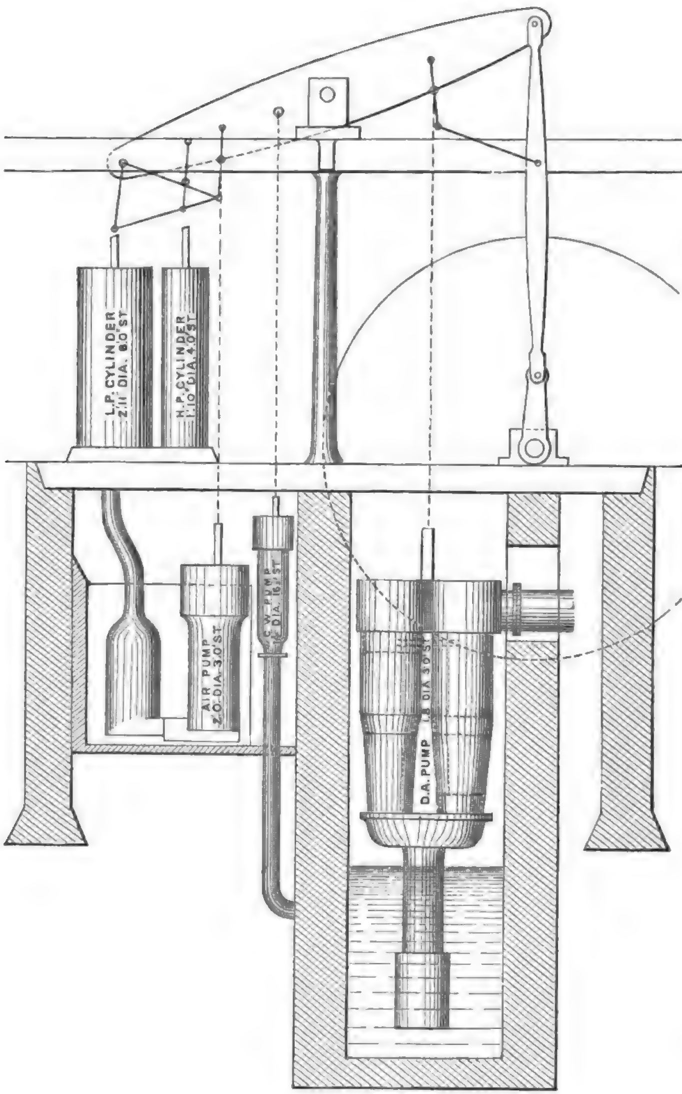
Fig. 13.



Scale ⅛ inch = 1 foot.

Portsmouth Waterworks.

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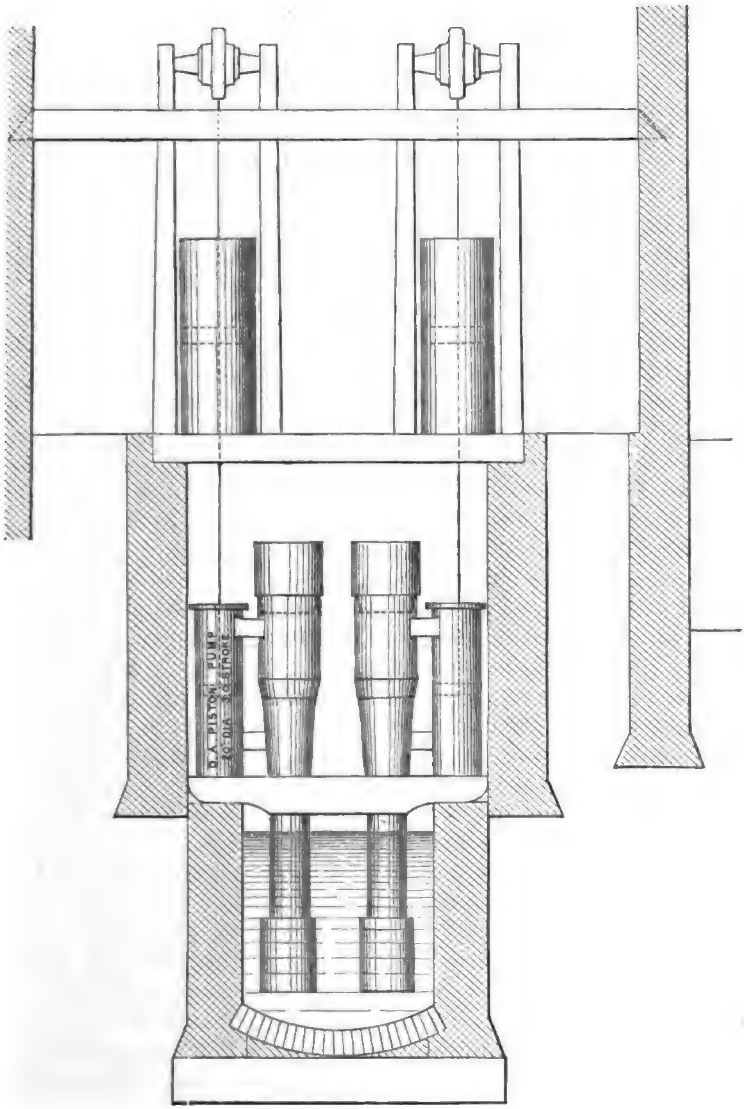
FIG. 14.



Scale ¼ inch = 1 foot.

PORTSMOUTH WATERWORKS.

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arrangements had been made for removing the condensed water from the low-pressure cylinder more thoroughly than before, and the leading results then were—

Mean steam pressure in boilers	60 lbs.
„ weight of Newcastle coal per I.HP. per hour	2·36 „
„ „ steam „ „ „	21·9 „
Average speed in revolutions per minute . . .	16·19
„ I.HP..	285

The Portsmouth Waterworks, at Havant, have four engines arranged as in Figs. 13 and 14, and the entablatures of these also depend upon the engine-house walls, for their lateral stiffness. Two of these engines were constructed in 1859, and the third in 1867, and these were all unjacketed. A few months' experience of the fourth engine, erected in 1880, which was fitted with steam-jackets and expansion-gear, so convinced the Directors of the advantages of such fittings, that they ordered new cylinders similarly fitted for the older engines. The immediate result of the change, combined with an increase of boiler-pressure from 40 to 60 lbs., and a second main to the reservoir, has been a reduction of the fuel used to just about one-half its former amount. Of this saving it is estimated that fully 60 per cent. is due to the new cylinders and valves alone. The pump on each of the first three engines is of the double-acting piston type, with four valves, and it is placed on the crank side of the beam-centre, the diameter of the pump-piston being 20 inches, and its length of stroke 3 feet. These pumps have worked efficiently from the first, and the engine speed, which for twenty years was kept at about twenty-two revolutions per minute, has latterly been increased to twenty-five revolutions, with equally favourable results.

The South Essex Waterworks No. 2 engine, at Grays, Figs. 15 and 16, is smaller than the last, having cylinders only 15 inches in diameter, by 3 feet 1½ inch length of stroke, and 25 inches in diameter, by 4 feet 6 inches length of stroke, and two double-acting bucket-and-plunger pumps, 16 inches in diameter, at opposite sides of the beam centre. The cylinders are not steam-jacketed, and the main bearings for the beam gudgeons are supported on a cross-girder, which is carried, near the centre of its length, on two columns, standing on a light bed-plate, and at its ends is built into the engine-house walls. This engine worked for several years almost constantly, day and night, pumping at speeds varying from twenty-five to thirty revolutions per minute, against a head of 500- to 550-feet pressure in the delivery-main, and it had to develop the maximum power of

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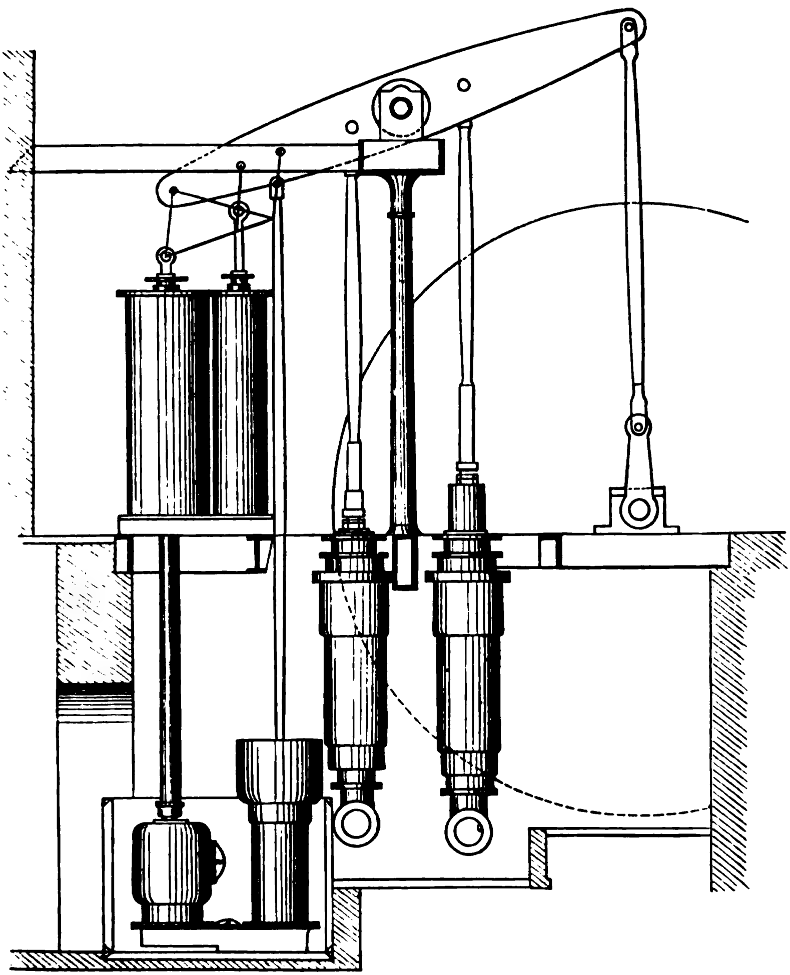
which it was capable, with 60 lbs. pressure of steam per square inch admitted throughout the high-pressure cylinder stroke, to

Fig. 15.



Scale $\frac{1}{12}$-inch = 1 foot.

South Essex Waterworks.

keep up this maximum pressure. The arrangement of the pumps is favourable to mechanical efficiency in this engine, and it

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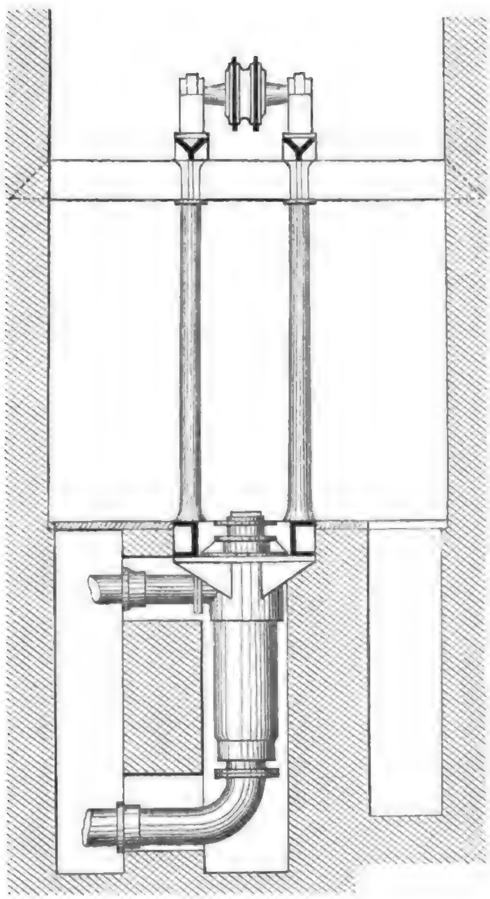
has been found in various trials, to range between 0·88 and 0·92. Its indicated power under maximum load was 81·5 HP., and the coal consumption in various trials has been about 3 lbs. per I.HP. per hour.

Fig. 16.



Scale $\frac{1}{16}$-inch = 1 foot.

South Essex Waterworks.

The two engines at the Doncaster Sewage Works are shown in Fig. 17; they have cylinders of the same sizes as those in the engine at the South Essex Works; but the engine is self-contained, with a full length bed-plate above the floor-level, and six columns for supporting the entablature. The pump is

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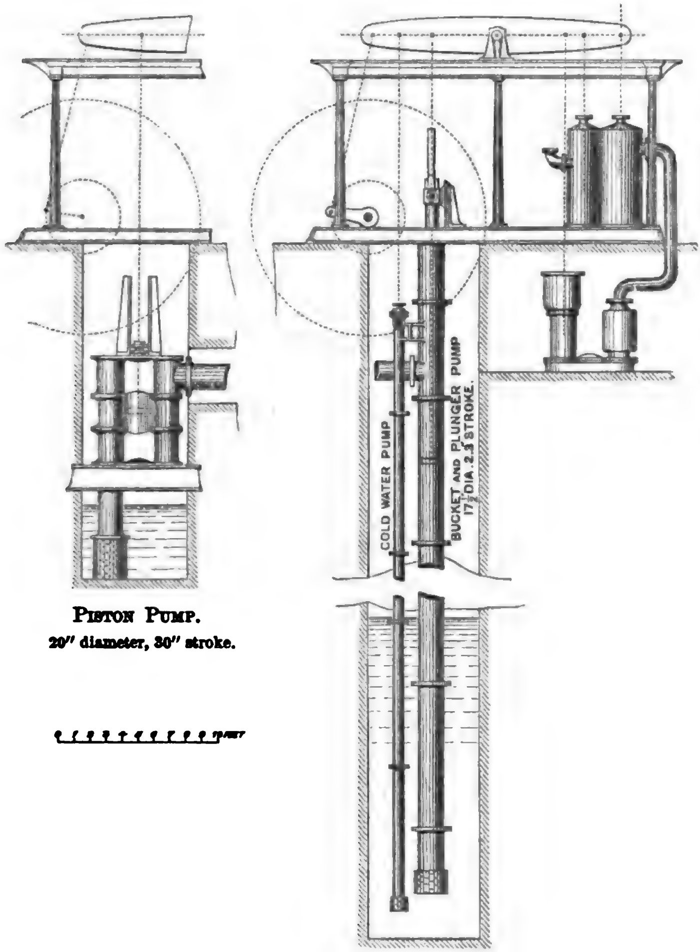
20 inches in diameter, with a length of stroke of 30 inches, of the double-acting piston type, on the crank side, and is fitted with inclined leather-faced valves, easily removable. The

Fig. 17.



Scale $\frac{1}{12}$-inch = 1 foot.

Doncaster Sewage Works. Saratoff Waterworks.

high-pressure cylinders are fitted with expansion-slides, but the absence of steam-jackets appears to deprive these engines of any advantage in steam and fuel consumption over the ordinary

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Woolf engines, taking steam throughout the stroke, as before described. Indeed, these gave worse results, since in one trial 34·09 lbs. of feed-water were supplied to the boiler per I.HP. per hour; but it is probable that with the very short period of admission, with a high grade of expansion, some of this was jerked over into the cylinder without evaporation, and so made the suspected steam consumption appear greater than the reality. The efficiency of the engine and pump was 0·86.

The two engines at the Saratoff Waterworks, in East Russia (Fig. 17), are of the same design as those at Doncaster, excepting that the cylinders are steam-jacketed, and they work a double-acting bucket-and-plunger pump 17½ inches in diameter, in a well on the crank-side of the beam centre. These engines have worked satisfactorily. The only mishap recorded of them was abnormal racing on one occasion, in consequence of pumping down the suctions and drawing air. The governors could not have been properly adjusted, or they would have checked them at once. The chief result of the accident was that the vertical suction-pipes were fractured, probably with the inertia of gulps of water occasionally jerked up them, when the engines were racing.

Two of the most efficient centrifugal pumping-engines in the Fen district, those at Whittlesea Mere and Ely, are made off the same patterns as the above.

The No. 2 engine at the Winchester Waterworks, with its pumps, is shown in Fig. 18. It spans a well 175 feet deep, and drives two lift-pumps 16½ inches in diameter, having 2 feet length of stroke at the bottom of it, for raising 900 gallons of water per minute to a reservoir at about the engine-room floor-level. The cylinders are not steam-jacketed, and the low-pressure is three times the volume of the high-pressure, which is considered to be a more favourable proportion under those circumstances.

Lambeth Waterworks, Brixton Hill.—In Plate 1 is represented the arrangement of two pairs of engines constructed in 1875–6 for pumping 5,000,000 gallons of water per day, when working together, from the reservoirs on Brixton Hill to that at Norwood, the normal lift including friction being about 230 feet. They were proportioned with a margin of safety of 10 for a maximum lift of 280 feet, and they have frequently been worked under a total lift of 320 feet and upwards. They were designed to meet the conditions and requirements set forth in a general specification prepared by Mr. John Taylor, M. Inst. C.E., the engineer to the company, and they were constructed and erected under his supervision and approval, Mr. T. F. Parkes,

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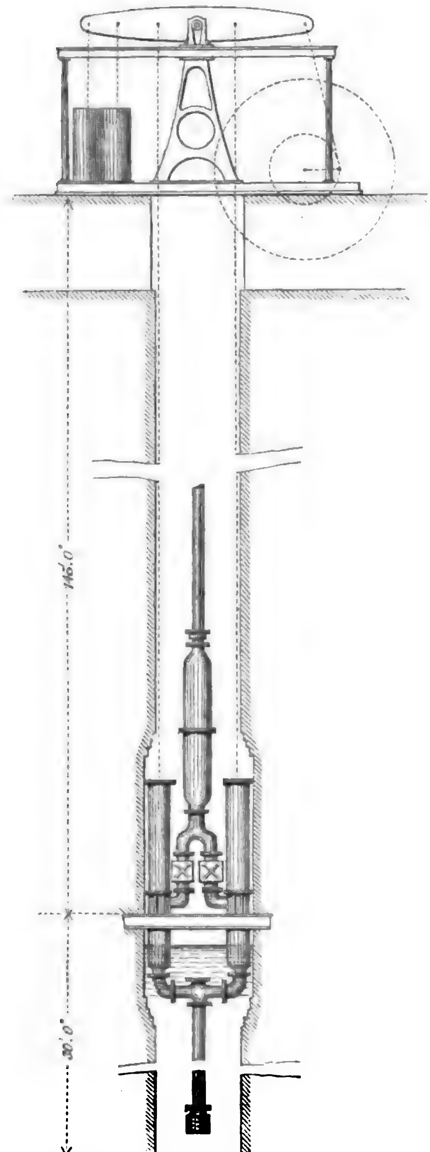
FIG. 18.



Scale $\frac{1}{16}$-inch = 1 foot.
WINCHESTER WATERWORKS.

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Assoc. M. Inst. C.E., being his resident assistant on the works during erection; but the details of the arrangement were left to a great extent to the judgment and experience of the constructing engineers, who were held responsible for their efficient working. Two arrangements, each designed to fulfil the specified conditions, were submitted. The first provided an engine of the Woolf type, of the same size as that for Brighton, with two pumps; the second with the high- and low-pressure cylinders on separate bed-plates, working on cranks at right angles, and each driving a double-acting pump, was recommended as being the most efficient under the circumstances, and was selected by the Lambeth Company. The price quoted was also £1,100 less than for the single engine. The first pair for raising 2,250,000 gallons of water was ordered in 1875, and the second (Plate 1 shows both pairs) Figs. 19 and 20, was ordered a few months later. The two pairs stand side by side in the same house, and are of the same type throughout, the only difference of consequence being that the second set has larger diameters and length of strokes to provide for 25 per cent. extra delivery. They are supplied with steam by five boilers in an adjoining house, each 7 feet in diameter, 21 feet 7½ inches long, with two internal flues 2 feet 9½ inches in diameter, the working pressure being 60 lbs. per square inch. They are set in roomy oven flues, on cast-iron chairs, so that no brickwork touches them beneath, and every part is freely accessible. The dampers in this arrangement are beneath the front ends, and lead through a tortuous main chimney flue to a somewhat distant chimney, which serves also for another range of boilers. Each boiler is furnished with a steam dome riveted over a perforated plate in the main shell, as prescribed by Mr. Taylor, and on entering the engine-room the main steam-pipe is furnished with a bottle-shaped "separator," in which the inertia of the drops of water carries them to the bottom, while the steam is diverted to an outlet at the side. As a result of these precautions the steam always enters the engines very free from moisture. Two of these boilers will supply steam to both engines working at full speed, but ordinarily three are worked at the same time.

The engine-house is a plain substantial brick building, 54 feet long, 35 feet wide inside, and 37 feet 6 inches high from the basement floor to the wall-plate. There are two complete masonry floors, the upper or main floor at the top of the engine foundation piers being 10 feet above the basement. Both floors are efficiently lighted by windows at the sides, so that every working part is accessible without artificial light. The foundations for the four

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engines consist of four parallel piers of brickwork, 6 feet 6 inches wide by 10 feet high, which cross the engine-room, with inverts and some arches between them, and gaps through them for gangways and to admit the pumps. These piers and the engine-house walls rest on a continuous bed of concrete 3 feet thick, which is bedded on the London clay beneath.

The larger pair of engines, shown in detail in Plate 1, has a high-pressure cylinder 22½ inches in diameter, and 5 feet 6 inches length of stroke on one bed-plate, and a low-pressure cylinder 45 inches in diameter by 5 feet 6 inches length of stroke on the other. Both cylinders are steam-jacketed and lagged, and fitted with double expansion-slides, those on the high-pressure cylinder being adjustable by hand while the engine is working. The steam exhausted by the high-pressure cylinder is re-heated and dried by passing through tubes in an inclined steam-jacketed casing, which conveys it towards the low-pressure cylinder. This arrangement aims at the same ends as the Cowper re-heater, and is simpler in its details.

Each cylinder stands on a massive cast-iron bed-plate, 23 feet 9 inches long, by 5 feet 4 inches wide, and 15½ inches deep, which is bolted down to the foundations, and is planed over its top surface for receiving the several frames and fittings which rest upon it. These are the crank-shaft pedestal at the end opposite to the cylinder; the A frames which support the entablatures in the centre; and light vertical columns at the ends. The valve-gear bearings are also secured to it near the cylinder. The entablature of each engine is in halves, bolted together over the A frames, and it is supported by them and by the end columns, which are of wrought iron turned and polished. The top face of the entablature forms a chequered platform 6 feet wide, which is protected with handrails, and surrounds the beam; and the several entablatures of the four engines are connected together with cross platforms and a central cast-iron staircase, which rises from the main engine-room floor.

The beams are made of wrought-iron plates riveted together, with cast-iron bosses riveted on, for supporting the several gudgeons, and lead counterweights to balance the pumps near their outer ends. The crank- and main-shaft, with the eccentric rods and all the valve-gear, are of polished wrought iron, and fully exposed to view above the floor-level, and the connecting- and pump-rods are of wrought iron of a round section. The fly-wheel is 15 feet in diameter, and of 7¾ tons weight.

The main-service pump in each engine is of the double-acting

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bucket-and-plunger type, with barrel 22½ inches in diameter, and a length of stroke of 2 feet 9 inches, and it is bolted direct to the underside of the bed-plate, midway between the cylinder and beam centre. It is worked by a rod off the same parallel motion as that which guides the piston-rod cross-head. The pump having just half the stroke of the piston, the parallel motion in both is quite accurate. A section of a pump, showing its valves, is given in Fig. 19. The pump-barrel is of hard cast iron, and the pump-bucket is packed with gun-metal spring rings ¾ inch wide in two grooves, two rings being in each groove. This arrangement of two rings in the same groove was first suggested to the Author by Mr. P. Brotherhood, M. Inst. C.E., several years ago, and it acts well. The idea is that one ring keeps the other lively, and so prevents their sticking fast. In the first engines the pump-barrels were originally lined with gun-metal, the pumps being packed with three gun-metal spring rings; but in a short time the clean gun-metal surfaces seized on one another, and in about eight months one of the barrels was worn completely through. In consultation with Mr. Taylor it was concluded that the similarity of the metals in the two surfaces was the cause, and by his advice the liners were removed, and new buckets were made to work in the larger cast-iron barrels. They have since acted very satisfactorily. The suction-clack in each pump is situated immediately below the bottom of the barrel, being pinched between its bottom flange and that of a short bend; the latter can be easily removed by breaking two joints, so as to expose the valves at any time without disturbing the working parts above. The valves, both in the clack and bucket, are of the annular ring type, with three concentric rings, falling on gun-metal seats in each valve, and heavy cast-iron guards above, regulating their descent. Each pump also has a flap retaining-valve on its delivery branch.

The water is raised from reservoirs behind the house, the water-surface level varying between the upper and lower engine-floor levels. Each pair of pumps draws water through an 18-inch suction-pipe, and then through a surface condenser, the water passing outside the tubes, which are ¾-inch in diameter and packed with wood ferrules. The two pump suction-pipes branch from the top of the condenser, and to equalize the flow as far as possible, in the 18-inch main suction-pipe, an air-vessel is placed over the condenser, with a capacity of about 280 gallons. The tube-surface in the condenser is about 2¼ square feet per maximum indicated HP. A larger proportion of area in the first engines was found unnecessary, and several tubes were removed with advantage. The discharges

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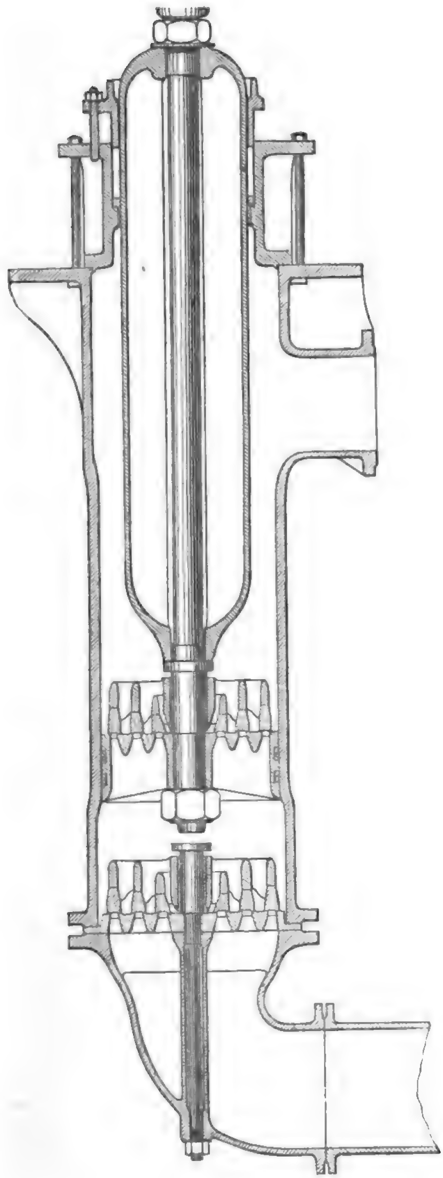
Fig. 19.



Scale ⅛-inch = 1 foot.

Lambeth Waterworks, Brixton Hill.

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from the two pumps meet in a tee-pipe, and pass thence through a 15-inch pipe to the air-vessel, 30 inches in diameter, which in an ordinary way contains about 280 gallons capacity of air, or three times the discharge of the two pumps together per revolution. A water-gauge on the side of the air-vessel shows a variation in the water-level of only about 2½ inches vertically per revolution. To prevent air entering the main easily from the air-vessel, in case the pressure should be reduced suddenly, the delivery-pipe from it is taken first vertically downwards to the lower floor-level, and then turns through the engine-house-wall to join the main outside. The air-vessel is supplied with air by an ingenious automatic apparatus, designed by the late Mr. Appold.

The engine air-pump is 15 inches in diameter, by 2 feet 8 inches length of stroke, its up-stroke capacity being about 2 gallons per maximum indicated HP., which is a fair proportion for surface-condensing engines. It discharges into a tank in the centre of the engine-house, from which the feed-pump takes its suction. It is worked by a rod from the beam of the low-pressure engine, on the crank side of it, while the feed-pump occupies a similar position under the high-pressure engine.

The condensed water from the steam-jackets, reheater, and separator, is collected in copper pipes, and conveyed to a central vessel so placed that the feed-pump suction-water passes through it and mingles with this hot condensation water on its way to the feed-pump. Thus any excess of steam passing through the jacket is rendered useful for heating the feed-water, which may always be served into the boiler at a temperature not far below the boiling point. A Porter's high-speed governor, actuating a throttle-valve, was originally fitted, but has been removed by the waterworks staff, being considered unnecessary, where attendants are always present. The normal speed of the engines is 22 revolutions, at which (with the pumps in perfect order, so as to deliver their full capacity) they should discharge 2,083 gallons of water per minute. The stipulated duty would allow a reduction of 5 per cent. off the full working capacity of the pumps. A travelling crane, capable of raising the heaviest piece, spans the engine-room above the engines.

The first pair of engines was started in December 1875, the second pair in February 1877; they have worked without mishap, and with great economy of fuel, from that time to the present. The lightness of their framing, and a certain amount of spring and vibration noticeable in their entablatures when the brasses require setting up, have been sometimes criticised adversely; but there is no perceptible vibration when the brasses are in good

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adjustment; and the Author submits that a moderate amount of spring and noticeable elasticity is not prejudicial in steam-pumping machinery, when it is self-contained.

There is some spring in the bed-plates under the main bearings, traceable to their being of an ornamental channel-section, with the blocks bolted on above them. This slight blemish has been overcome in more recent engines, by making the bed-plate of a strong box-section there, and casting the block on.

There can be no question of the strength and stability of the engines, as they have a margin of safety of 10 throughout, and their occasionally pumping on lifts considerably higher than that for which they were designed, and their withstanding, without injury to themselves, the strain of starting against a closed cock in the main, above alluded to, are evidences in their favour. Two trials have been made with these engines, but on neither occasion did the service arrangements of the Water Company permit of their being extended over eight-and-a-half hours.

The first pair, tried in March 1876, when on special high-service duty, pumping under an average lift of 321·4 feet, with a mean steam-pressure of 59 lbs. per square inch, and expanded 8 times in the cylinders, gave a steam consumption in the cylinders, exclusive of that used in the steam-jackets, of 17 lbs. per indicated HP. per hour. The mean revolutions were 19·44, the indicated HP. 156·8, and the useful HP. in water lifted 141·9, corresponding to a mechanical efficiency of 0·905.

In a trial of both pairs of engines working together, and doing their normal duty, on the 18th of July, 1877, the mean pressure of steam was 54·4 lbs. per square inch; lift, 225·8 feet; speeds of engines, 21·21 and 20·17 revolutions per minute respectively; steam consumption, 16·8 lbs. in the cylinders, 2·8 lbs. in the jackets: in all, 19·6 lbs. per indicated HP. per hour in the A and B engines; and 16·6 in the cylinders, 2·7 lbs. in the jackets: in all 19·3 lbs. in the C and D engines. The mechanical efficiency was 0·901 in the A and B engines, and 0·896 in the C and D. The water in passing through the surface-condensers was raised in temperature, as nearly as could be read on ordinary thermometers, by about $2\frac{1}{4}°$ Fahrenheit; thus showing a rise in temperature by condensation with economically-working engines of about 1° per 100 feet of lift.

The total cost of these two pairs of engines, with their pumps and five boilers, travelling crane and all other engineering apparatus connected with them, was £21,905, and the engine- and boiler-houses, with the foundations and flues, cost about £6,000.

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The Antwerp Waterworks engines, briefly described in Mr. Anderson's Paper,[1] are of the same power and main centres as the C and D Lambeth engines, but they have both high- and low-pressure cylinders on each bed-plate, which is cast in one piece with the main crank-shaft bearing, and the beams and connecting-rods are of cast iron. The foundations are of a similar character to those at Brixton; a special feature in both cases being that all the working parts of the pumps and gear throughout are readily accessible.

No. 3 Sutton engine, Plate 3, is an example of one fitted with three pumps all sucking from one well; but discharging under different heads of pressure. It shows preeminently the advantages of a beam-engine, when such various duties are to be performed by a single motor. It would be difficult to make a satisfactory arrangement of a horizontal-engine driving pumps of similar sizes in a well. All the pumps are of the bucket-and-plunger double-acting type, and at 22 revolutions per minute, and at full bore, they throw as follows:—

	Inches.		Inches.				Feet.
Low-service pump	18	diameter	33	stroke	= 650	gals. per minute	182
Middle-service pump	12	„	36	„	325	„	291
High-service pump	14	„	$16\frac{3}{4}$	„	200	„	526

Ordinarily all three pumps work together, doing these respective duties; but they are so arranged that either one of them can be shut off readily without stopping the others, and the working parts having considerable surplus strength, their delivery-pipes are fitted with interchangeable connections and cocks, so that any one pump may take any other duty, and thus the medium-sized pump often works into high service, and the largest pump into middle-service, while the smallest pump takes one of the lower-service duties. This engine is fitted with a surface-condenser and a circulating-pump for forcing water through it.

The Buenos Ayres sewage pumping-engines, Plate 2, were constructed in 1883, and are considered to embody most of the principles, which the recent practice of the Author's firm has shown to be most desirable in large pumping-engines. They are arranged in two coupled pairs, but any one engine can work singly. Each pair works four pumps arranged as shown, under a gross lift of 50 feet, the sewage raised being 13,100 gallons per minute at 15 revolutions, which is their normal speed to do the

[1] Minutes of Proceedings Inst. C.E., vol. lxxii., p. 35.

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work specified, or 17,500 gallons at 20 revolutions, their maximum speed. The bed-plates and A-frames are throughout formed in cellular box-sections, and are very much more rigid and stiff in themselves than any engines which have preceded them. The A-frames are carried up to include the beam-gudgeon bearings at their top ends, and they are stiffened transversely by box-section distance pieces, bolted between them, just below the beams. The spring-beams in this case are supported at one end by the walls; but the only strains conveyed to the walls, are half the vertical components of the angular pulls on the radius-rods, which are comparatively of little consequence. The high-pressure cylinder in each engine is 24 inches in diameter with 46 inches length of stroke, and the low-pressure 36 inches in diameter with 72 inches length of stroke, the cylinder ratio being 3·5 to 1. The cylinders are steam-jacketed, and the high-pressure cylinders are fitted with expansion-valves of the Author's improved type, so that the engines can be worked at very low speeds.

One of the service-pumps is driven by the high-pressure piston-rod, extended through the cylinder bottom, with such arrangements, however, as will permit of the pump being opened out, and a bucket removed readily. The other pump is worked off the beam, at the crank side of the centre.

To enable a single rod to be used, for working this pump, without fouling the lower end of the engine connecting-rod, the crank-shaft centre has been pushed 1 foot further from the engine centre than the low-pressure cylinder, and the outer end of the beam has been turned upwards to enable it to work the crank-shaft in its new position, in a satisfactory manner, without increasing the stroke.

Possibly some engineers of æsthetic tastes may criticise this design of beam; but the Author submits that no objection can be offered to it on the score of its mechanical principles, when it is introduced in an engine in which the beam-gudgeon bearings are so stiffly supported as they are in each of these engines.

The air-pump and feed-pump, are worked off a small beam beneath the main floor, which is actuated by links off a cross-head on the high-pressure piston rod.

Each of the service-pumps is of the single-acting lift type, with barrel 41 inches in diameter and a length of stroke of 46 inches. A section through one of them and a plan of the bucket and clack are shown. It sucks through a 36-inch pipe from the pump well beneath, and discharges through a 27-inch pipe into the air-vessel and 3-feet main between the engines forming each pair.

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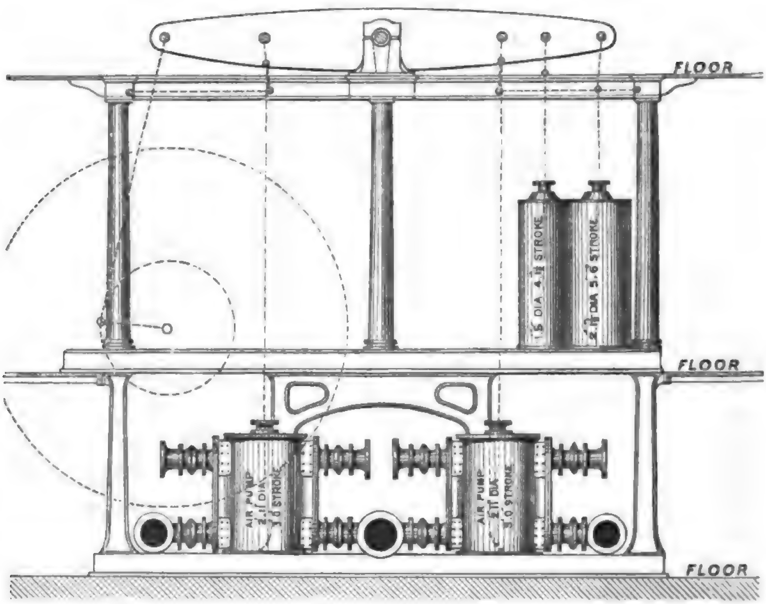
The four pumps of the pair of engines have a joint discharge-capacity per revolution of 876 gallons, and the average volume in the air-vessel is 1,290 gallons, being 140 A for pumps so arranged, as per diagram 12.

The machinery is arranged in the pumping station according to the plan in Plate 2. The boiler-house, containing four boilers, each 7 feet in diameter, 23 feet long, with spaces for two extra boilers, and workshops adjoining, is placed at the back of the engine-house. Each boiler has two internal flues, 2 feet 9 inches in diameter, fitted

FIG. 20.



Scale 1/8-inch = 1 foot.
GENERAL POST OFFICE.

with 6 Galloway legs, and terminating at the back end in eighty-eight 3-inch tubes, 6 feet long. Ordinarily two boilers with one pair of engines will work at a time.

The buildings, when completed, will present an imposing appearance, being of a highly ornamental character; they are being erected alongside a railway, at a distance of 10 miles from Buenos Ayres. The engines and pumps are guaranteed to give a duty of 100 millions of foot-lbs. in water raised per cwt. of coal; they have been constructed throughout under the supervision, and to the specification of Mr. J. F. La Trobe Bateman, Past President Inst.

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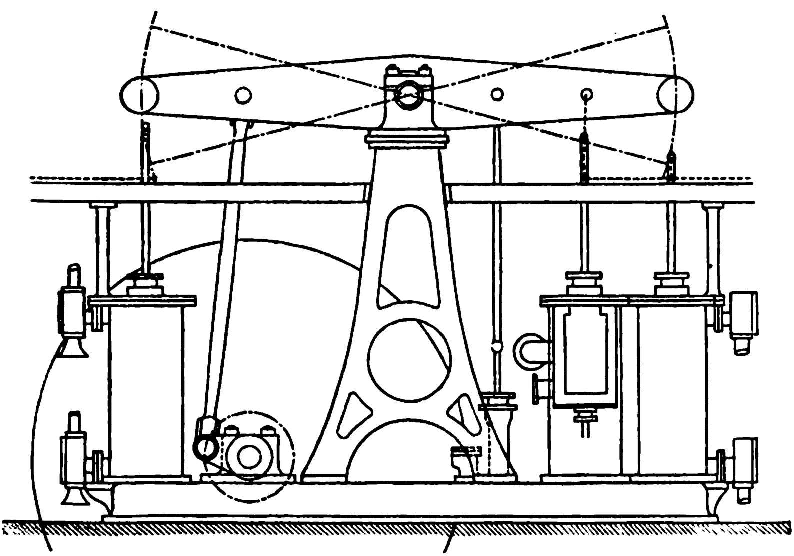
C.E., the Engineer to the Buenos Ayres Improvements Commissioners.

At the General Post Office four beam-engines, arranged as shown in outline in Fig. 20, actuate air-pressure and vacuum-pumps for working the whole of the Pneumatic Despatch system of the Telegraph Department in London. To avoid transmitting any vibration to the buildings which surround the yard in which the engines are erected, no part of them touches the walls, the only connection possible being through the concrete on which they rest. They are enclosed in a light building of timber and glass.

Fig. 21.



Scale ¼ of an inch = 1 foot.
Prudential Assurance Office.

Each engine has two main bed-plates, each about 25 feet long, in one casting. The lower one is bolted down to the concrete bed which forms the floor of the yard, and it carries two air-pumps and four frames, which support the upper bed-plate, on which an ordinary Woolf engine of the same size as that at Winchester, Fig. 18, is erected.

The pumps and pipes are so arranged that any pump may be worked either for pressure or vacuum, and any engine may either work its pumps, both doing one duty, or one pump may be compressing while the other is exhausting. The pumps are double-acting, with barrels 35 inches in diameter and 36 inches length of

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stroke. The normal air-pressure is 10 lbs. above the atmosphere, and the vacuum 8 lbs. below the atmosphere. These engines have kept up day and night duty, without a single mishap causing intermission, ever since they were started in 1873.

Two small single-cylinder beam-engines, for effecting similar duties on a small scale, at the Prudential Assurance Office in Holborn, are shown in Fig. 21. The arrangement is simpler and less expensive *pro ratâ* than that of the larger Post Office engines. The steam cylinder is 16 inches in diameter by 2 feet length of stroke, and the air-pumps at the ends of the engine are 16 inches in diameter by 3 feet length of stroke. Ordinarily, one pump works for vacuum and the other for pressure. They maintain a speed of 45 revolutions per minute very satisfactorily. The leather-faced air-pump valves have been in use for more than three years without being replaced, and they work inaudibly. Recently some vacuum pumping-engines for a sugar factory have been constructed to the same centres as those last described, the pumps in this case being of the single-acting type, 18 inches in diameter and 36 inches length of stroke, with india-rubber foot, bucket, and head-valves, working on grids.

In all the above examples the pumps have been worked direct from the beam; but many small beam-engines are arranged to run at a high speed, and drive three-throw pumps at a lower speed by spur-gearing. Fig. 22, showing the pumping machinery at the South Hants Waterworks, is an example of this arrangement. There are two small Woolf beam-engines, each of which runs at 45 revolutions per minute, and drives two sets of vertical three-throw pumps, with barrels 8½ inches in diameter, and 2 feet length of stroke, at 24 revolutions per minute. One of these sets of pumps raises 350 gallons of water per minute, from the well in the chalk to the settling reservoirs, in which the Clarke process is carried on; and the other raises the softened water from these reservoirs to the service reservoir on Southampton Common, 12 miles distant. The mechanical efficiency cannot be so good as in pumps driven more directly; but this arrangement has many advantages in some cases, and as evidence that the above machinery works well, it is worth mentioning that the Chairman of the South Hants Water Company, at the recent annual meeting, reported that not sixpence had been spent in repairs at their pumping-station since the works were opened five years ago.

The Paper is accompanied by numerous illustrations, from which Plates 1, 2, and 3 and the figures in the text have been prepared.

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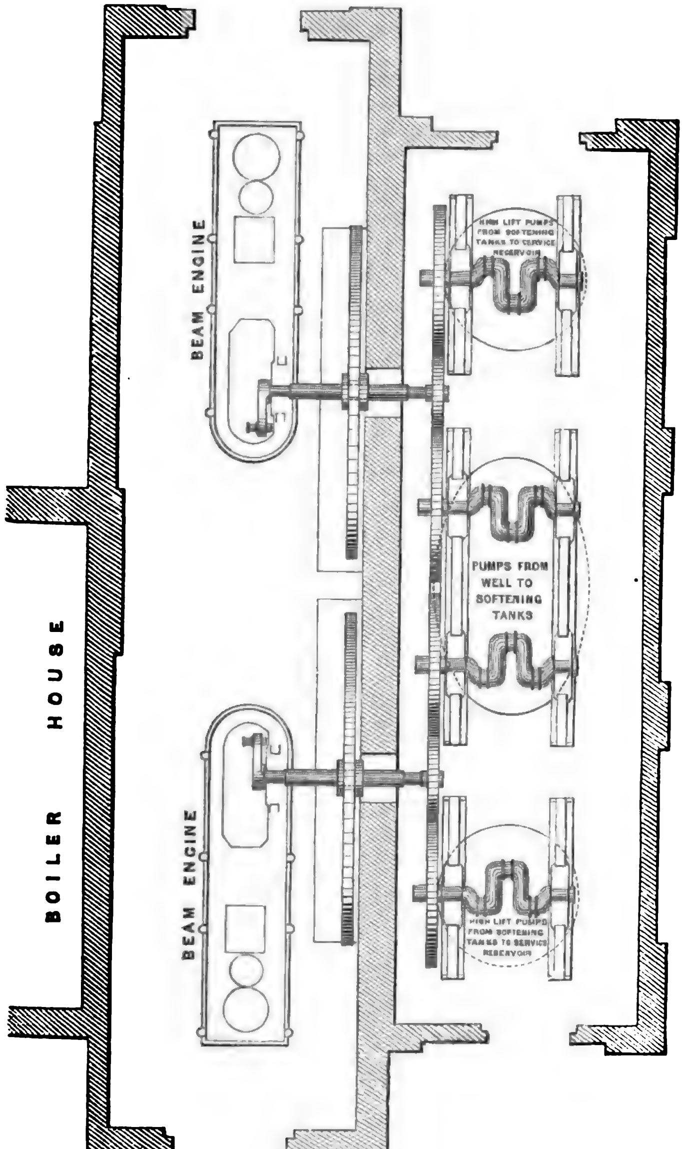
FIG. 22.



Scale ¼-inch = 1 foot.

SOUTH HANTS WATERWORKS.

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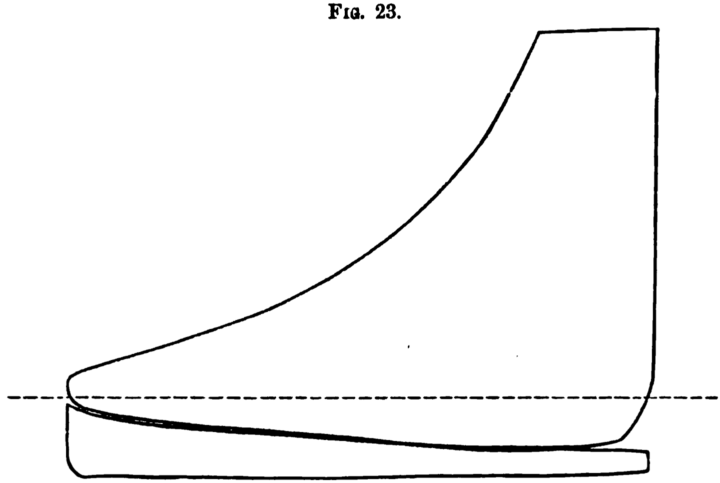
Discussion.

Mr. Rich. Mr. RICH said he had added two more diagrams, Figs. 23 and 24, to exemplify the effect of steam-jacketing, and the injurious effect of any moisture left in the cylinder. Fig. 8 in the Paper was given as an extreme case of high expansion in unjacketed cylinders, where he considered that the low-pressure diagram was absolutely worthless. The two diagrams, Figs. 9 and 10, were also from unjacketed cylinders, working slowly at twelve to thirteen revolutions per minute, the first taken one hour and a half, and the second five hours after starting, without materially altering the load. Figs. 23 and 24 were from steam-jacketed cylinders of the same comparative volumes, viz., 4 to 1, and working under very similar

FIG. 23.



circumstances. Comparing the highly expansive diagrams, Figs. 8 and 23, it would be seen how much larger the low-pressure card was in the jacketed cylinder, Fig. 23; and the same remark applied on comparing Figs. 3, 9, and 24. In Fig. 9 the maximum steam pressure indicated in the low-pressure cylinder was below the atmosphere; while in Fig. 24 it was about 15 lbs. above the atmosphere. These diagrams confirmed graphically the many other evidences of the immense gain due to steam jackets especially in slow-speed engines.

The Paper, he was sorry to say, described no engines other than those constructed by his own firm; but he was sure that there were many members present who were well acquainted

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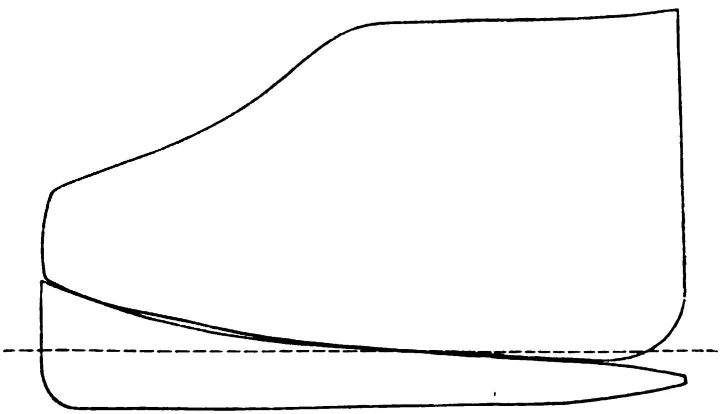
with the design and high performances of beam- and horizontal-engines in various countries. It might be invidious to refer to them, but he might mention Mr. Davey, who was noted for his very ingenious differential-engines, and Mr. Donkin, whose performances with horizontal-engines were well known by the records in the Proceedings of the Institution. He might also mention that the finest horizontal-engines in the Paris Exhibition were those of Messrs. Galloway. Mr. Rich.

FIG. 24.



Mr. E. A. COWPER said he took exception to one or two statements in the Paper. One of them was that steam-jackets were little used in 1854. The well-known firm of James Watt and Co. had used steam-jackets ever since the time that Watt told steam-users in 1769 "to keep their cylinders as warm as the steam that entered them," and many others had done the same. If they did not do that, they lost a large quantity of steam on the first admission into the cylinder, as he had lately tried to demonstrate. He had himself adopted steam-jackets before 1854; he did not therefore see why they should have been left out, in so many of the engines referred to in the Paper, half of which had no steam-jackets at all. He supposed the Author had brought them forward as examples to be compared with the better practice of putting on steam-jackets. He also took exception to the statement with regard to wrought-iron beams. Many of the best steam-engine manufacturers in Cornwall, London, and other places, had never discontinued the use of cast-iron beams because one had broken. Some persons had adopted wrought-iron beams, but he did not think they were advisable in pumping-engines as they sprang too much. Cornish engines received the full pressure of steam Mr. Cowper.

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Mr. Cowper. in the one cylinder, and surely if those beams would stand, the double-cylinder compound engines would endure the moderate amount of strain they had upon them. In designing beams he always calculated the amount of material for the required strength, and then added metal for the purpose of making the beam heavy. He specified the weight of the beam. A good engine with a heavy beam worked more satisfactorily from the momentum and inertia in the weight of the beam, which gave better opportunity for expanding the steam. He objected to any springing or jumping either in the engine-beam or in the engine-framing. A pumping-engine should have a solid foundation, and in order to prevent springing of any kind, he preferred a straight column, thus giving a straight line of metal from the point of strain to the foundation. He did not think that any fancy shape could be as stiff as a column down to the solid masonry; and "A" frames could not be so satisfactory in consequence of their springing. Indeed he had seen some "A" frames that would have been much better if they had been tied into the walls of the house. He did not notice in the Paper any comparison between the engines in regard to the economy of coal, though the title of the Paper was "The Comparative Merits of Engines for Pumping;" he should have been glad to see what coal had been used in each case, and particularly in the best engines with steam-jackets. It had been stated that all the engines were not steam-jacketed as late as 1877; he was much astonished at this, as he thought the value of steam-jackets had been appreciated long before that date. He was happy to find that the pumping-engine at Brixton was put forward as one of the best. But the quantity of water used as steam was too large. The steam-jacketed reservoir had not been made exactly as he wished, but as a pipe with a number of small pipes inside, and the steam outside. The quantity of water was 16·7 per I.HP. per hour. The quantity of coal was not given. A pair of engines by another firm put up for the same Company required only 13·39 lbs. of water per I.HP. per hour in the cylinders, exclusive of that required for the jackets, which could not be measured, as the pipes were connected to the boilers. The steam-jacketed reservoir was made in the way he preferred having the same capacity as the large cylinder, so that there was room for the high-pressure cylinder to deliver steam into the steam-jacketed reservoir, and as the steam passed into the low-pressure cylinder it was warmed up by the steam-jacketed sides of the reservoir; a pair of indicator diagrams off such an engine were shown in Figs. 25 and 26.

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The fact of the low-pressure cylinder being at 150° when the attempt was made to get the steam to work in it was very remarkable, and was a clear proof that steam-jackets were absolutely wanted in making a good engine. A small pair of 15-HP. engines, which he had designed for Brixton, required 2·4 lbs. of coal per I.HP. per hour, while the larger engines at Ditton consumed only 1·55 lb., the Clifton engines, 1·95 lb., the Lambeth engines, Mr. Cowper.

FIG. 25.

HIGH PRESSURE.

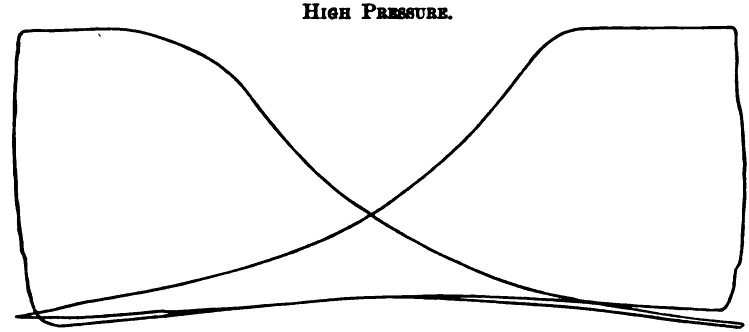
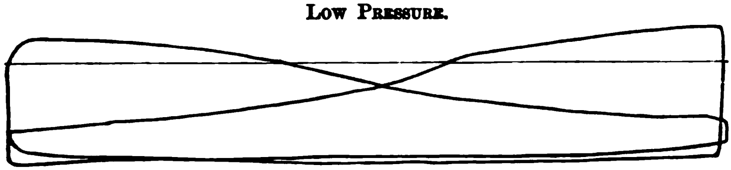


FIG. 26.

LOW PRESSURE.



LAMBETH WATERWORKS, BRIXTON, 120 HP. ENGINE.

Steam 40 lbs. in boilers.	Revolutions, 18 per minute.
Vacuum 26 inches in condenser.	Head of water, 330 feet.

High pressure cylinder—diameter, 28½ inches, stroke 5 feet 6 inches.
Low pressure cylinder—diameter, 45 inches, stroke, 5 feet 6 inches.

I. HP.	HP.	59·3
I. HP.	LP.	100·0
	Total I. HP.	159·3

1·6 lb. The engines of H.M.S. "Briton" required 1·98 lb. on the measured mile, going at "full power," and 1·3 lb. at 10 knots' speed. Those engines had been constructed under the direction of Sir E. J. Reed, M. Inst. C.E., and gave great satisfaction. What form of engine was the best for a given purpose, often depended upon the circumstances of the case. All would agree that it would be ridiculous to propose to send heavy beams and column beam engines 600 miles up-country on bullock-wagons, where in many places, there were no roads. Parts of horizontal pumping-

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Mr. Cowper. engines had been so sent, and the engines were now working at 2·22 lbs. of coal per HP. on the water, which would be about 1·88 lb. per I.HP. per hour. In the case of a direct-acting engine of small size over a well, "A" frames were admissible provided there were very substantial girders under them. But where an engine of a large size was wanted for waterworks purposes, and carriage was easy, nothing would beat a good sized beam engine with heavy beams, well built into the engine-house walls, with a good foundation below, the cylinders being steam-jacketed at the top, bottom, and sides, with steam cut off before half-stroke in both cylinders, and with a steam-jacketed reservoir between the cylinders. With reference to the Cochrane evaporative surface-condenser he might mention that he arranged them for the late Sir William Siemens' 180-HP. engines. They consisted of two large cast-iron pipes or cylinders 12 feet high, that being the ordinary length of large pipes. One was placed within the other, leaving about an inch of space between them into which annular space the steam passed, whilst water trickled down both outside surfaces.

The wrought-iron "surface evaporative-condensers," made by Mr. Loftus Perkins, also answered well; also 4 inch horizontal cast-iron pipes. In some cases he had used copper-pipes with advantage, but they cost more; these had been used for many years for sugar vacuum pans, and afterwards by Messrs. Pontifex for an engine at Coombe's Brewery before he had adopted iron-pipes for the purpose.

In 1856 he introduced iron surface evaporative-condensers for factory or mill-engines, and the first compound engines on his plan in the Exhibition of 1862 had a wrought-iron surface evaporative-condenser, with the result of only one twenty-fifth part as much water being required as with an injection condenser or a surface-condenser. Thus where there was a deficiency of water a first rate economical engine could be used, with a consumption of only one-third as much water as was necessary for a common high-pressure engine; which in fact might mean saving the cost of sinking a well for the supply of the necessary amount of water.

With reference to the ordinary surface condenser, he believed he was responsible for presuming to raise the temperature of the whole of the water pumped by a waterworks engine, a very few degrees, by passing it through a surface condenser, and thus obtaining a good vacuum in the engine, without any special cold water pump, properly so-called. He had first

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done this in the small Brixton engines for the late Mr. James Simpson. Mr. Cowper.

Mr. W. Schönheyder said the Paper principally turned on the relative merits of beam- and horizontal-engines, and the Author stated that nearly all the engines made by James Watt and his successors were beam-engines; in that statement he thought lay the explanation of the fact that since that time many more beam-engines had been made than horizontal-engines for pumping purposes, especially in England. When Watt first made his engines they were used for pumping purposes, and when he turned his attention to mill-engines, he naturally made them in the same form, simply adding the crank-shaft and the crank. He did not think that Watt considered the question whether a horizontal- was better than a beam-engine; but he merely followed the previous pattern, and the same conservative principle had led many engineers to follow his example. No doubt a beam-engine was much more costly; but it had some conveniences as compared to the horizontal-engine. The German and Swiss engineers, as the Author had stated, had found them too costly, and they very properly adopted horizontal-engines in many cases. But because they adopted a particular form of engine, that was no reason for making an inefficient one. Because, in a beam-engine, the crank-shaft brass was divided horizontally, that was no reason why the same thing should be done in a horizontal-engine. The strain was in a different direction, and different brasses should therefore be adopted. He did not think the brass shown in Fig. 4, was unnecessarily complicated. If portable-engine makers adopted them, surely the makers of large mill-engines ought to do the same. He quite appreciated the statement of the Author as to the error of having brasses for horizontal-engines divided at the slope of 45°. He had seen many bad examples of it, notably one case with a large mill-engine with a 14-inch crank-shaft. The plummer-block was originally designed for adjustment in horizontal directions, but unfortunately the engine got into the hands of a so-called "practical" man who had never seen anything of the kind before, and he took the block away and substituted one with the brasses divided at 45°, and the consequence was that the shaft had never kept cool since. The Author had alluded to some continental engineers having adopted what he called the "refinement" of turning the piston-rod to a curve, so that when it was in the engine and supported at both ends by guide-blocks, and the weight of the piston was in the centre, the rod was straight. That was no "refinement," but only

Mr. Schönheyder.

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Mr. Schönheyder. a natural method to adopt. If in comparatively rough work like bridge-building the girders could be made with a camber, so that when the load came upon them they should not be hollow, surely a similar thing could be done with a piston-rod in an engine. He would be glad if the Author would state in what year the German engineers first adopted the cambered piston-rod, and how they did it. In 1872 it occurred to Mr. Schönheyder that it would be an advantage to camber the piston-rod in some manner, and he devised a method which differed considerably from what had been the practice previously. It was understood to be an advantage to camber a piston-rod, but he did not think it had been previously done in the right way. Some engineers turned the rod first, and bent it, after heating it, to an approximate curve; but that was of course an imperfect method. Others turned the two ends of the rod separately, so that each end was straight; but that was not satisfactory. What he did was to make the rod first of all in its rough state, approximately with the amount of camber that it was calculated to have, then turn the centre of the rod for the piston to fix on, and make the end centres in the rod so as to allow for the calculated deflection; he next put the piston-rod in the lathe and sprung the centre of the rod down into a bearing so as to be in a line with the two end centres, and he finally turned the two ends of the rod. The effect was that with a proper calculation for deflection when the rod was in the engine supported at both ends, with the piston in the centre, it would be perfectly true and the piston would not press on the cylinder. He found, however, that engineers were very conservative and did not care to adopt the method, and they would not do so unless there was a demand for it. As to the difficulties of making the rod of the exact camber, it was not necessary that there should be the precise deflection due to the load; the rod might be made with a slightly greater camber, and the effect would be that the piston, instead of pressing against the bottom of the cylinder would press a little against the top, and that would allow for the rod being afterwards reduced; in course of time it would require returning, and then probably it would be slightly too weak, but in that way the unnecessary wear on the bottom of the cylinder would be obviated. Carrying the weight outside, sufficient surface could be provided for it with very little friction. In some cases a straight rod would have 2 inches deflection, so that 2 inches camber would have to be given to the rod in order to carry the whole of the weight of piston entirely on the outside. The system of having two pitches for screws on valve spindles, which the Author

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claimed as being new, had been adopted many years ago. The Author had alluded to some difficulties that he had found with a horizontal suction-pipe 40 feet long. Mr. Schönheyder had encountered a difficulty with a suction-pipe only 13 feet long in the case of a vertical pumping-engine. No doubt each case should be calculated in order to ascertain whether it was necessary to have a suction vessel to meet difficulties of that kind. Mr. Schönheyder.

Mr. W. E. Rich wished to make a short explanation. With regard to the question of coal-consumption, particulars as to which Mr. Cowper said would be desirable. He purposely avoided giving the coal-consumption except in one or two isolated instances, as he thought it was better to limit the subject to the consumption of steam rather than that of coal, as was done by most engineers now who paid attention to steam-engine testing. The comparative merits of engines *per se* could then be determined without relation to the boilers, which should always be tested independently. Mr. Rich.

Mr. B. Walker observed that there were many points in the Paper with which he cordially and entirely agreed. There were many others with which he disagreed, and he proposed to occupy a short time by discussing what the Author had said about the horizontal-engine. He started his Paper by criticizing adversely the ordinary crank-bearing horizontal-engine, and he referred to some engines working diagonally at right angles, that there was a great deal of knock in those engines, and that had attracted his attention to the consequences of having a pressure first in one direction and then in another in any crank-bearings. The engines that the Author had referred to must have been very badly constructed, or they had not been adapted to receive the shock in both ways. If a machine was constructed to do its work, of course knock would not take place; but if it was constructed with too little wearing-surface, knock would very readily and easily happen. The Author said that the crank-shaft rimered out the bushes. That expression to an ordinary mechanist was very suggestive, but he had never found a good mechanical engineer who would turn a fly-wheel shaft into a rimer. He had always found a mechanical engineer try to make his shaft smooth, and give as much surface as possible for the shaft to work upon, so as to avoid any tendency to rimer. It was easy to construct a crank-bearing of such dimensions that it would not wear in any degree—the oil would float the weight and no wear would take place. He had given an example of horizontal-engines that had been at work for thirty years, in which the crank-neck was Mr. Walker.

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Mr. Walker. as good now as at the beginning. Several years ago he made for a firm in Birmingham some compound-inclined direct-acting engines, under the direction of Sir Frederick Bramwell. The brasses were of such proportion and material that they would never wear out. There was plenty of surface; they were made of phosphor bronze cast in chills and therefore the oil protected them completely. The shaft was of steel, and the bush and the whole contrivance was constructed not with a view to repair it, but to prevent it from wanting repairing. The neck that the Author exhibited in Fig. 4 was, in his opinion, a very bad design. If the engine was working at any great speed it would soon fail by the pieces becoming loose. Provision was made in that bearing for what ought never to take place. His firm were at present erecting at Grimsby some very large horizontal-engines working through the "L" lever. The firm for whom the engines were being made would have a beam-engine were it better. He believed that the horizontal-engines they were making would last as long, and be as economical in steam, as a beam-engine. The Author referred rather seriously to the very heavy piston that had to be dragged backwards and forwards along the cylinder. During the last fifteen years he had tried a large number of cylinders on pistons for horizontal-engines made of boiler-plate riveted together of solid rolled armour-plate 3 or 4 inches in thickness, and also of cast iron; and he would say most emphatically that the broad cast-iron piston was the best, and if that piston was constructed of sufficient breadth to carry its own weight, it being constantly surrounded by steam, no wear comparatively would take place. The engines that had been at work for thirty-five years had certainly not worn in the vertical direction. If worn at all, they were worn horizontally. That sometimes took place with a well-constructed engine from the crank-neck not working exactly true. With a broad piston, well constructed, no wear would take place whatever; the idea of turning the piston-rod in a sort of curve to make it wear easily was a fallacy. He was much surprised that the Author should have overlooked the advantage of the heavy piston. He knew quite well the great advantage arising from having something to start. If there was no body for the steam to drive against, the start was not anything like so good. The heavy piston had this great advantage, that it received the elastic shock of the steam at the beginning of the stroke, and delivered it economically near the end of the stroke to the fly-wheel shaft, and therefore he considered that the Author had overlooked in this case what he was

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quite well aware of, namely the benefit of the weight being started first, and, after it had been started, being allowed to expend itself on the fly-wheel. The next item was the horizontal air-pump. So far as the air-pump pure and simple was concerned, all other circumstances being the same, he would rather have a horizontal than a vertical, because he could get more work done at the same cost. A horizontal air-pump was easily made double-acting, and then more use was got out of it for the same prime cost. The Author laid great stress upon the necessity of the valves being at the bottom of the cylinder, in order that at each alternate stroke the cylinder might be cleared of its water. About ten years ago his firm made some large horizontal compound engines, and with a view of settling the question of getting out the water, they put the valves at the bottom. Two or three years ago they made another pair of engines direct-acting, with cylinders 60 inches in diameter, and for a pressure of 80 lbs. of steam, and they put the valves at the top. They did not find any difficulty in getting rid of the water. The water came out entangled with the steam, as dust was entangled with the wind as it blew along. If any activity was given to the engine, the water would soon get out of it; if it was sluggish, going slowly on, the water might be allowed to drop down, and not get out as it ought to. It was impossible to overrate the value of jacketing the cylinders, and compounding the cylinders, when it was intended to work economically. His firm were now engaged in constructing a pair of the largest horizontal-engines, direct-acting, for rolling purposes, that had ever been made. They would weigh 400 tons; the high-pressure cylinder was 44 inches in diameter, the low-pressure 60 inches, with a 5-feet length of stroke. They would work up to a high speed. These engines had been designed by Mr. Richards of Bolckow and Vaughan's, who had had great experience with compound engines. They were to be erected in Spain. Coal was very dear there, and therefore it was desirable to use the least possible quantity of fuel. His firm had also just completed a pair of large compound engines for the Butterley Company, to be erected at Codnor Park. Therefore it would be seen that, on the point of jacketing steam-cylinders, and compounding steam-engines, the Author and he were entirely agreed. The Author seemed to think the fact of the ordinary blast-engine being made vertical settled the question of the great advantage of vertical-engines. Another element was introduced in the blast-engine—the heat arising from compression of the air. That could not be

Mr. Walker

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Mr. Walker. lubricated so easily, there was not the steam going in and out of it; and further, the valve-motion could not be much better arranged when the cylinder was placed vertically. Further on the Author said that when the engines were large and vertical he advised that they should be coupled together at right angles. With that he entirely disagreed. A great deal of strain took place, and the engine was not at liberty to work so economically. With a common mill-engine that would be right, but with a blast-engine, or even with a pumping-engine, it was wrong. They coupled the Bessemer blowing engines together, because they received very prompt instructions to start; but with the blowing engines the best practice was to have the cylinders separate, to work each engine separately. The Author referred to the speed of the beam-engine, and from the way in which he put it, it would seem that high speeds could be obtained by the use of a beam-engine. He should like the Author to say if he had ever known a beam-engine with 5-feet length of stroke, and with cylinders 60 inches in diameter, working at 1,500 feet a minute, or one hundred and fifty revolutions. Any beam-engine subjected to such a speed would very soon break down; it could not live under such shocks.

The Author had directed attention to the waste of public money by many of the petty corporations and local authorities. He had omitted to mention Sir William Armstrong's horizontal pumping-engines, some of which had been at work for twenty or thirty years. He saw a pair of them not long since, and a Newcastle man said he had been twenty-five years with them, and they were very little the worse for wear. It was not a question of economy, but of which was the best for the purposes for which Sir William Armstrong applied his horizontal pumping-engine. He would say that it was better than the beam-engine or the direct-acting engine. The Author asked whether modern continental engineers were right in having horizontal-engines. In the main, in his opinion, they were right. A man bought a steam-engine to get work out of it at the least possible cost, and if a steam-engine that would turn a mill, or pump, or roll iron, could be obtained for less money when made with the cylinder horizontal it was better to have it. The Author spoke of a manufacturer whose capital was productive of 8 per cent. Mr. Walker thought it should have been 0·8. Some large engines had been made and put to work for driving mills on the Continent, and had not been very successful from trouble arising with the cylinders. Large vertical engines had lately been erected

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at Ghent, which undoubtedly were marvellous examples of good work, but also of high cost. One pair of engines cost £44,000, but few people would expend £44,000 in order to produce 2,000 HP. The Author referred to beam-engines with beams made of wrought iron, and he mentioned that Cockerill in Belgium made beams with a box-girder section. He did not approve of that form of girder, but thought the plain cast iron was the best, and Mr. Walker entirely agreed with him. Wrought-iron girders became loose, and if subjected to much work they would surely fail. A little further on the Author spoke of making the beams in two castings, and said it was better to have them in one casting, as castings made at different times were not homogeneous. He could not understand what that meant. If two girders of the same kind of material were cast in the same way, and put side by side, was it to be understood that those two girders were not equally well adapted for carrying the load, or that the little bit of variation that would take place in the hardness or softness of the two castings would not be made up by a little more or less spring in one of them? Mr. Walker.

Mr. J. G. MAIR said it was difficult to make a general comparison of the relative values of horizontal- vertical- or beam-engines, as each had their separate functions. Where the level of the suction water admitted of a horizontal-pump being used, the horizontal-engine with its pump in line behind it was undoubtedly the simplest and cheapest form of pumping-engine that could be adopted; and the large number of horizontal-engines now made, both for mills and pumping, was one of the strongest proofs of the favour in which that type was held. Mill-engines were now almost always made horizontal even up to 10 feet stroke, and if the machinery was for service abroad, where carriage and foundations were very expensive, horizontal-engines were alone adopted, as at Kimberley in Africa. Where the water-level was some depth below the floor-line, the beam- or vertical-engine allowed of the best arrangement of pump, unless quadrants were used, as was now often done for collieries and deep wells. The cost for repairs he did not think was more in one case than the other, provided both types were equally well designed and cared for; but beam-engines required least attention, and were not so liable to get their cylinders scored and damaged through imperfect lubrication. As an example of a well-kept horizontal pumping-engine, he might mention one made about twenty-five years ago by Messrs. Simpson and Co. for the West Middlesex Waterworks, which had not had its cylinder re-bored, Mr. Mair.

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Mr. Mair. nor was it worn more oval than the piston-rings would spring up to. The engine and pump had each a length of stroke of 5 feet, and ran at 28 to 30 revolutions per minute. So much depended on the form of pistons used and the lubrication, that when a horizontal-engine had its cylinder scored or worn oval, it was generally the fault of the design of piston and want of attention. One of the best points in favour of the beam-engine was the mass that was in it to receive the initial blow that passed through the engine at the commencement of each stroke; and, in fact, the heavier the beam the better. As an example of that, he would cite a 100-inch Cornish engine at the Grand Junction Waterworks, where one of the flitches of the beam cracked some five years ago. He put 14 tons of wrought-iron straps round it, and after that the engine used less steam and worked better than before. The strain due to the initial blow of the steam was reduced by the inertia of the reciprocating parts, which varied as the weight of them multiplied into the squares of their velocity. Light moving parts were therefore of advantage, as could be seen by the fast-running horizontal- and vertical-engines now made; but with pumping-engines, which were to a certain extent slow-running, mass was wanted, therefore the beam was of advantage. Splitting up the expansion by means of the compound system also reduced the initial blow, but even then the slow-running horizontal compound was subjected to heavier stresses on the shaft bearings than was the beam. He did not agree with the Author about vertical treble-valved air-pumps as a horizontal air-pump was equally effective if properly designed, and water was no more liable to get into the cylinder than with vertical pumps, and in neither case could it do so unless through great carelessness and ignorance on the part of the driver. He might mention that there was a horizontal air-pump exceedingly efficient that had not treble valves but only one valve. It was made by Pollitt and Wigzel, of Sowerby bridge. It was a single-acting piston pump, and as the piston passed by a large number of holes in the pump-barrel the condensed steam and air rushed in, and on the upstroke it was forced out through one valve only. He had seen one of those engines where the condenser was picking up its own water through a length of pipe 90 feet long and from a depth of 24 feet, so that he did not think anything could be claimed for having a treble-valved pump. He had not met with any undue wear on horizontal-engine brasses, provided they were angled as they usually were, and most certainly that was not a point on which to condemn horizontal-engines. He

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agreed with the Author that for slow-running pumping-engines the beam-engine was the best type, and as the first cost was only about 25 per cent. greater than a horizontal-engine it ought to be always adopted where first cost was not a serious objection. He did not like the A frames adopted by the Author, as they were not so rigid as old-fashioned entablatures and spring-beams attached to the walls. He, however, thoroughly approved of his remarks as regarded the waste of public money by companies and public authorities, and also by private persons, in purchasing the cheapest machinery that could be found. Economy in working and in steam consumption ought to be the first consideration. The best engines described by the Author used 19·3 and 19·6 lbs. of steam per I.HP. per hour. One engine on a trial in 1876 is reported to have used 17 lbs., but this must only have been working steam and could not have included the jackets, as in November 1880, four years after the trial, the Author stated, in the discussion on Mr. Walker's Paper on "Machinery for Steel-Making, by the Bessemer and the Siemens Processes," that the smallest quantity of steam passing through the cylinders and jackets that he had arrived at was 19·7 lbs., and that he had great difficulty in obtaining that result.[1] Other engines were described by the Author as using from 23·8 to 34 lbs. He hoped that engineers would not think that these figures represented the best work of Woolf or compound-engines, as single-cylinder engines of good design and properly jacketed only used about 20 lbs. The non-condensing portable engines at Cardiff in 1872 consumed about 24½ lbs. He had described in a Paper "On the Independent Testing of Steam Engines, and the Measurement of Heat used,"[2] a compound-engine that used about 15 lbs. of steam per I.HP. per hour (Diagram E); and to state that economic compound-engines used from 19½ to 34 lbs. was, if he might use the expression, a libel on the compound principle, and likely to bring it into disrepute. The Author had given the efficiency of some engines and pumps as 92 per cent. This was of course on the pump-bucket displacement, and not on measured water, as the engine pumped into service-mains. He believed that the pump must have been slipping a large quantity of water for so high an efficiency to be obtained. In the brake trials that had been made, and published in the Mulhausen papers, with powers from 40 to 150 HP., the average was about 88 or 89 per cent.; that was without a pump, and he did not believe it was possible to get 92 per cent. out of an Mr. Mair.

[1] Minutes of Proceedings Inst. C.E., vol. lxiii., p. 16. [2] *Ibid.*, vol. lxx., p. 313.

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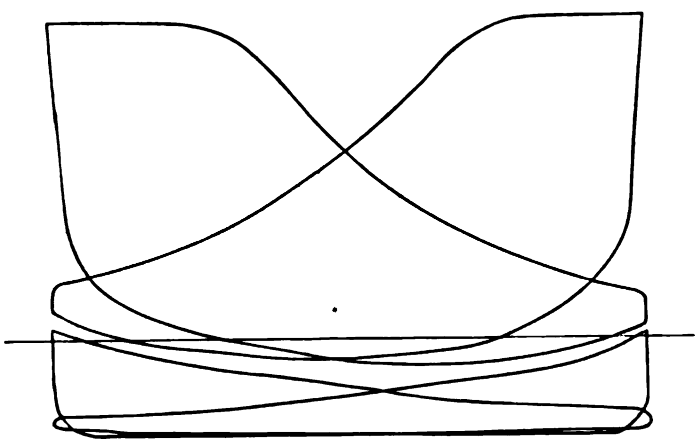
Mr. Mair. engine with a bucket and plunger pump attached to it. Several indicator diagrams were given by the Author, which were very much what one would expect from steam distributed by a "small D slide" in unjacketed and badly proportioned cylinders, and it was astonishing that the Author had not designed all his engines with steam-jackets before 1877. He exhibited some drawings of engines which his firm, Messrs. Simpson and Co., had made for the London Water Companies to exhibit at the Health Exhibition, (Plates 4 and 5), and in addition seven sets of diagrams (Figs. 27 to 35), which were lettered to correspond with the drawings of the engines from which they were taken.

Engine A was one of a pair recently erected for the West

A. Fig. 27.



Scale $\frac{1}{16}$.

West Middlesex Waterworks, Hammersmith.

I.HP. HP.	114·02
I.HP. LP.	108·10
Total I.HP. . . .	222·12

Consumption of steam per I.HP. per hour 15·65 lbs.

Middlesex Waterworks Company. The low-pressure cylinder was 47½ inches in diameter by 8 feet length of stroke; high pressure, 29 inches by 5 feet 5 inches, and the double-acting piston pump was 18 inches in diameter by 8 feet length of stroke.

Engine B, one of a pair made for the East London Waterworks Company, had a low-pressure cylinder 39 inches by 6 feet

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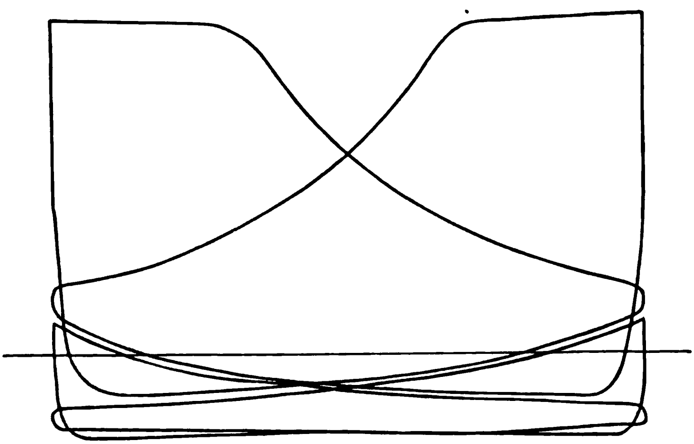
6 inches stroke, and a high-pressure 23 inches by 4 feet 5 inches. **Mr. Mair.** The pump was a double-acting bucket-and-plunger pump, 22½ inches in diameter, by 5 feet 7 inches length of stroke. He had not measured the heat through the engine, and therefore could not give the steam consumption, but Mr. Bryan, M. Inst. C.E., the engineer to the company had, he believed, measured it, and found it to be 16 lbs. of feed water per I.HP. per hour.

B. FIG. 28.



EAST LONDON WATERWORKS, "DUKE."

I.HP. HP.	55·2
I.HP. LP.	52·7
Total I.HP. . . .	107·9

Scale $\frac{1}{16}$.

Engine C had been recently erected for the Lambeth Waterworks Company at their Surbiton Station. It had a low pressure cylinder 37 inches by 6 feet 6 inches, and a high pressure of 22 inches by 4 feet 7 inches, and ran at 30 revolutions, equal to 400 feet piston-speed per minute; there were two double-acting piston pumps, one each side of the beam, but even without large plungers it was impossible to attain 92 per cent. efficiency, and he did not know how the Author could get it with the large bucket-and-plunger pump shown by Fig. 19, where there was seemingly so much more friction.

Engine D was one of a pair of McNaught engines with intermediate receiver erected for the Lambeth Waterworks Company at their Brixton Station. The cylinders were 32 inches by 6 feet,

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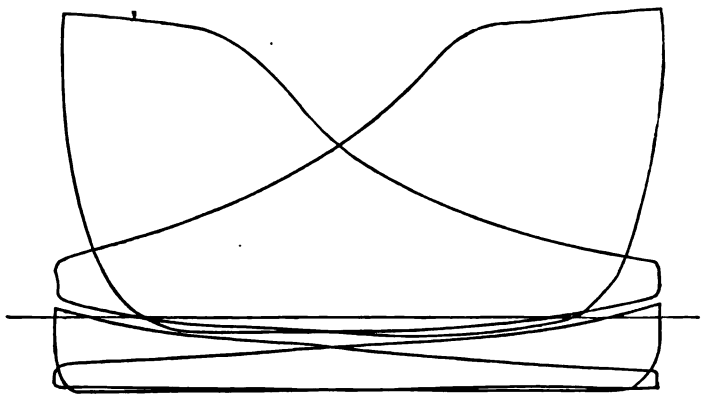
Mr. Mair.

C. FIG. 29.

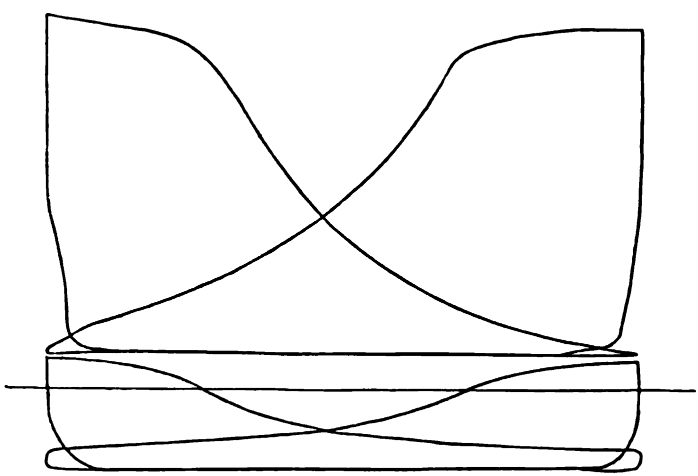


LAMBETH WATERWORKS, SURBITON.

I.HP. HP.	97·0
I.HP. LP.	97·0
Total I.HP. . . .	194·0

Consumption of steam per I.HP. per hour 15·12 lbs.
Scale $\frac{1}{32}$.

D. FIG. 30.



LAMBETH WATERWORKS, BRIXTON.

I.HP. HP.	63·8
I.HP. LP.	86·4
Total I.HP. . .	150·2

Consumption of steam per I.HP. per hour 17·8 lbs.
Scale $\frac{1}{30}$.

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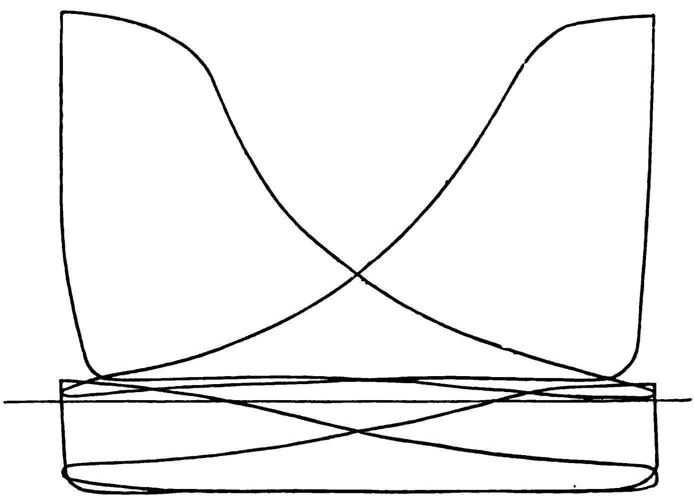
and 24 inches by 3 feet each, working a double-acting bucket-and-plunger pump, the speed being 30 revolutions per minute, the steam consumption, 17·8 lbs., was high, owing to the great distance of the engine from the boilers causing the steam to be moist. These engines were practically balanced, a cylinder being on each side; but he could not get more than 85 or 86 per cent. efficiency out of them. Mr. Mair.

Engine E was one of two made upon Mr. E. A. Cowper's system, with high- and low-pressure cylinders working cranks at

E. FIG. 31.



DITTON LOW LIFT ENGINES—"COWPER SYSTEM."

I.HP. HP.	60·0
I.HP. LP.	67·4
Total I.HP. . . .	127·4

Consumption of steam per I.HP. per hour 14·84 lbs.

Scale $\frac{1}{16}$.

right angles, the steam being warmed up during the passage from the high- to the low-pressure cylinder in one of Mr. Cowper's heaters or "hot pots." The cylinders were 36 inches and 21 inches in diameter, by 5 feet 6 inches length of stroke. Two plunger-pumps were driven from each beam. He would direct attention to the extremely low consumption of steam. The diagrams F and G were from an engine at Chatham Waterworks, and illustrated the economy of the steam-jacket.

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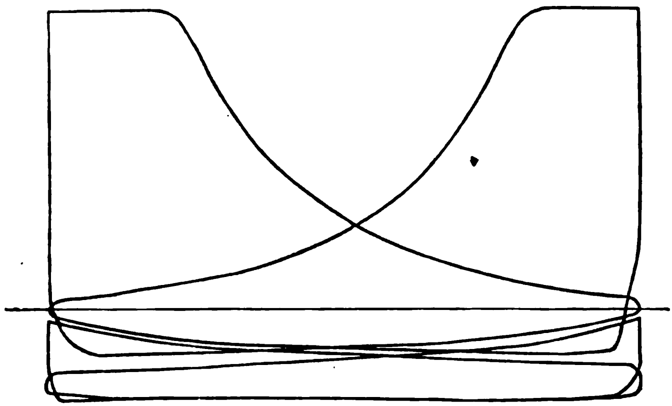
Mr. Mair.

F. Fig. 32.



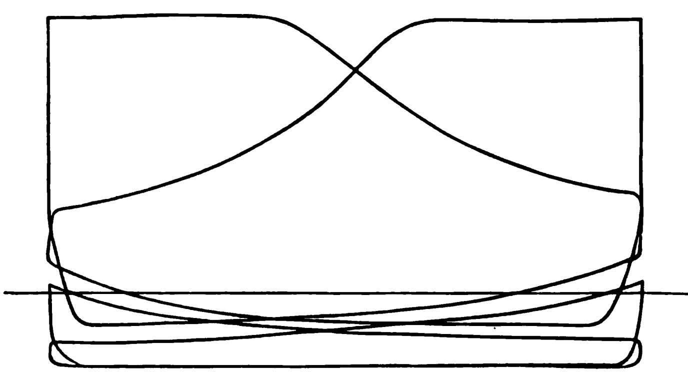
Chatham Waterworks. Steam in Jackets.

I.HP. HP.	35·4
I.HP. LP.	39·8
Total I.HP. . .	75·2

Consumption of steam per I.HP. per hour 17·34 lbs.

Scale $\frac{1}{16}$.

G. Fig. 33.



Chatham Waterworks. No Steam in Jackets.

I.HP. HP.	44·6
I.HP. LP.	31·3
Total I.HP. . .	75·9

Consumption of steam per I.HP. per hour 26·62 lbs.

Scale $\frac{1}{16}$.

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All the trials were made in the most careful manner; the feed-water was measured into the boiler, the temperature and pressure of the steam were noted so that the heat could be measured into the engine, and the temperature and quantity of the air-pump discharge were also taken, and that enabled him to measure the heat from the engine, and in this way to check the steam consumption. He had made no mention of coal consumed, for although that was a most important question for the manufacturer, his object was to ascertain the efficiency of the engines. Eighteen beam-engines, with their low-pressure cylinder 46 inches by 8 feet and high-pressure cylinder 28 inches by 5 feet 6 inches, had been constructed for the Lambeth, Chelsea, and New River Waterworks Companies, the original design having been prepared by Dr. Pole and Mr. David Thomson, MM. Inst. C.E. They worked bucket-and-plunger pumps, and some of them had been at work for more than thirty years. They all had entablatures and spring beams built into the walls, and the cylinders were completely steam-jacketed. They had given great satisfaction in work, and the cost of repairs was remarkably small.[1] Plate 5, Figs. 8 and 9, represented a pair of vertical engines working low-lift pumps at the Chelsea Waterworks Company's intake at Molesey; the cylinders were 28 inches in diameter by 4 feet length of stroke. A bucket-and-plunger pump was worked off a prolongation of each piston-rod. Plate 5, Figs. 10 and 11, represented a pair of horizontal pumping-engines at the Haggar Lane Station of the East London Waterworks Company. The cylinders were 24 inches in diameter by 3 feet length of stroke. The piston-rods were continued through the back cover and connected to piston and plunger pumps. Plate 5, Figs. 12 and 13, showed two engines constructed for the New River Company for pumping from a well in the chalk. The pumps were driven from vertical cylinders 32 inches in diameter by 3 feet length of stroke through bell cranks. There were two bucket-and-plunger pumps to each engine. These engines were fitted with Joy's gear; and this was, he believed, its first application to a pumping engine. The horizontal compound engines made for the Odessa Waterworks[2] had worked in a most satisfactory manner for a long time. No new parts had been ordered, and the repairs and renewals had been of the most trivial nature. Mr. Mair.

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[1] Minutes of Proceedings, Inst. C.E., vol. xxiii., p. 69. Institution of Mechanical Engineers. Proceedings. 1862, p. 269.

[2] "A Practical Treatise on the Steam Engine." By Arthur Rigg. 1878. Plate 77.

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Mr. Mair. He had brought these diagrams, drawings and data before the Institution as he considered they represented better and more varied types of pumping-engines than those given by the Author.

Mr. Moreland. Mr. R. MORELAND said his experience had been that horizontal-engines were superior to beam-engines in all respects for general purposes. No doubt many cheap engines were still made with angular crank-shaft brasses, but the best practice for many years had been to divide the brass into three or four parts with independent adjustments. The well-known Corliss engine had been so fitted for the last twenty years. Nor had he found the cylinders of horizontal-engines wear faster than those of the beam- or the vertical-engine. With suitable metal and guides, and by carefully packing the underside of the piston, his experience had been that a properly constructed horizontal-engine running at 400 feet per minute would not require its cylinder to be re-bored for fifteen or twenty years at least; and generally he had found the repairs of beam-engines were considerably in excess of horizontal-engines doing the same work. There was no difficulty in balancing a horizontal-engine to run at great speeds with perfect steadiness. With respect to the Author's description of the patented valve-spindles of differential pitch to equalize the cut off at each end of the cylinder, he was informed that his manager had done the same thing with Messrs. J. and H. Gwynne's pumping engines, several years ago; he then believed it was original, but was anticipated; and he had heard that it was applied to some blowing-engines constructed some ten years ago in the northern counties. Passing to the consideration of what seemed to be the Author's special design in the Paper, viz., to demonstrate that beam-engines were superior to horizontal- or vertical-engines for pumping purposes, he agreed that horizontal-engines were not in many instances suitable for heavy pumping, as they generally involved a considerable length of suction pipe, which was almost fatal to the easy working of large engines. Each case must be decided upon its own merits; but he was of opinion that generally speaking the inverted vertical direct-acting rotative engine had on the whole the greatest number of advantages and good points. The principle of direct action had been extensively applied in such cases as that of blowing-engines, &c., but its application to pumping, although sure to extend, was as yet comparatively limited. The advantages of direct action might be thus summed up:—I. The pressure of the pistons was directly transmitted to the pump-piston or plunger.—II. The number of working parts and weight of the same were considerably diminished.—III. The final cost and that of maintenance were both

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sensibly reduced.—IV. The foundations, space required, and the building cost were lessened.—V. The direct-acting engine could with ease and comfort be run at a higher speed than the beam-engine. There was no difficulty in balancing the working parts of direct-acting engines by the fly-wheels if the engines did not exert more than 100 HP. For engines of 150 HP. and upwards, it was desirable to fit a small balance lever, which was also convenient for working the small auxiliary pumps. The time occupied in disconnecting these engines and getting at the pistons or pumps, did not exceed the time required for this purpose in a beam-engine. From a number of vertical direct-acting engines in use that had been constructed by his firm, he selected those supplied to the Eastbourne Waterworks. He had prepared a tabular statement of the results of a twelve hours' trial, conducted by Mr. George A. Wallis, M. Inst. C.E., and his firm. The engines were independent, vertical, rotative, direct-acting, and each drove a bucket-and-plunger pump, and raised the water from a well about 78 feet deep, measured from the engine-house floor, and pumped directly into the mains. The maximum head against which these engines had to pump was 400 feet. No. 1 engine worked up to 160 I.HP., Nos. 2 and 3 to 100 I.HP. each. The general dimensions of the large engine were as under:—High-pressure cylinder, 20 inches in diameter; low-pressure cylinder, 38½ inches in diameter; pump working barrel, 20 inches in diameter; length of stroke of engine and pump, 40 inches. The average revolutions per minute during the trial were 23·44, and the duty per pump HP. 124,600,000; the coal per I.HP. was 1·53 lb., and per pump HP. 1·78 lb., including ash. Nos. 2 and 3 engines of smaller dimensions gave a duty of 105,800,000. The speed of the large engine was limited by the necessity of getting the suction-valve out at the top of the pump, as the pumping power available was not sufficient to lower the water-level to enable the suction-valve to be got at below; otherwise, with large valves, the engine could be run at 35 revolutions; it worked very well indeed at 26 revolutions. The proper speed of the engines Nos. 2 and 3 was 30 revolutions per minute, but had to be reduced to the speed given in the Table, about 20·8, to avoid excessive pressure in the main, in ordinary one engine only being in use on this service. Mr. Moreland.

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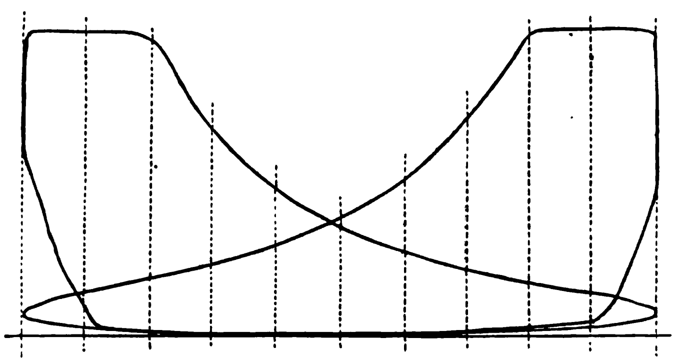
Mr. Moreland.

OBSERVATIONS and RESULTS of TWELVE HOURS' TRIAL.

	No. 1 Engine.	No. 2 Engine.	No. 3 Engine.
Water raised in gallons	759,456	374,040	376,020
Average revolutions per minute	23·44	20·78	20·89
„ lift, in feet	243·94	335·40	341·48
„ steam pressure, in lbs.	69·15	74·92	74·92
Pump HP.	77·97	52·80	54·00
Indicated HP.	90·70	Collective	124
Coal consumed including ash, in lbs.	1,666	„	2,688
„ per pump HP. including ash	1·78	„	2·097
„ per I.HP. including ash	1·53	„	1·800
Duty per 112 lbs. of coal in water raised in millions of foot-pounds	124·6	„	105·8

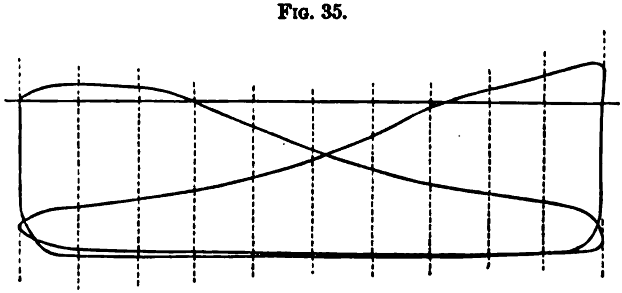
The fires at the commencement and close of the trial were equally charged with coal. Figs. 34 and 35 were specimens of indicator

FIG. 34.



Cylinder 20 inches in diameter × 40 inches length of stroke.
Boiler pressure 70 lbs. per square inch.

FIG. 35.



Cylinder 38¼ inches in diameter × 40 inches length of stroke.
Boiler pressure 70 lbs. per square inch.

diagrams taken simultaneously from the high- and the low-pressure cylinders of No. 1 engine during the trial.

As a confirmation of the result obtained by a direct fuel trial,

the heat rejected by the air-pump discharge of No. 1 engine was carefully measured on several occasions, and the results differed very little from each other. Particulars of a trial upon the same day as that when the full trial was made were given in the Table. The general result was that 281·3 pound-degrees of heat were rejected by the engine per minute per pump HP., and that the steam used, including the supply to the jackets, was 18 lbs. per pump HP. per hour, and 15·46 lbs. per I.HP. The feed-water was drawn from the hot well, and the condensed water from the steam-jackets circulated back to the boilers. Mr. Moreland.

HEAT TEST, No. 1 ENGINE.

Duration of test	64¼ minutes.
Revolutions of engine per minute	24·69
Total head	308·24 feet.
Temperature of injection	47°·5 F.
" of discharge	72°·25 F.
Rise in temperature	24°·75 F.
Total quantity of water delivered by the air-pump into a tank	76,110 lbs.
Water discharged per minute	1,180 "
HP. of water raised	103·81
Pound-degrees of heat rejected per HP. of water raised per minute	281·3
Steam used per pump HP. per hour calculated from the heat discharge, allowing for radiation	18 lbs.
Ditto per I.HP.	15·46 lbs.

Very high percentages of efficiency between the indicated and the pump HP. were generally not a proof that the engine was mechanically perfect, but that the pump was not filled at each stroke; and this might partly explain the Author's statement that the efficiency of the Lambeth engines in water pumped went up to 92 per cent., or within 8 per cent. of the indicated HP.

He would finally remark that it was especially desirable that all pumping-engines should be independent, not coupled, as such a contingency as the breaking of a crank-shaft would render both engines unserviceable.

Professor ALEXANDER B. W. KENNEDY said the later and larger portion of the Paper formed a most valuable descriptive account of an important type of pumping-engine. With that larger portion Professor Kennedy did not propose to concern himself, but he should like the opportunity of saying a few words about the first and shorter part, on which he disagreed on some points with the Author. The Paper raised three questions: first, as to the relative advantages of vertical- and horizontal-engines; secondly, as to the relative advantages of beam-engines and direct- Professor Kennedy.

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Professor Kennedy.

acting engines; and, thirdly, as to the relative advantages of rotating and direct-acting engines for pumping purposes. The third point was one of great complexity. The Author, however, had treated it rather by way of description than of discussion, and he should not refer to it at present, but would confine himself to the other two points. It might be, of course, that vertical-engines as such were distinctly better than horizontal, but still that if the vertical-engines had to be beam-engines their disadvantages would be considerable as compared with direct-acting engines. The grounds of preference which the Author put in the forefront of the question—the wear of the brasses—might perhaps be elevated into too much importance. Out of England one certainly did not find that there was any difficulty in making double-adjustment plummer blocks; for every little maker on the Continent thought he could make them in a way that would be satisfactory. He would, however, like to emphasize the point, which the Author of course knew quite well, that the pressure in any brasses could be along one line only at any one instant as well with a horizontal- as with a vertical-engine. At different instants, *i.e.* at different parts of the stroke, the position of this line always varied, as well in vertical- as in horizontal-engines. Probably in vertical-engines, however, the variation of the direction of pressure was not so great as in horizontal. He thought, however, that in most horizontal engines the variation was not so great, but that if the resultant of the pressure and the weight of the heavy shaft, &c., were carefully determined, the brasses could be so angled that the wear could be taken up by adjustment in one direction. Of course, it required careful design, and he admitted freely that vertical-engines had less variation in the direction of pressure than horizontal. But there were two other points of design which he should be inclined to put more in the front than the point mentioned by the Author. They were these; first, that he should like to place all framing as far as possible in the line of stress, and, as a corollary, that he very strongly objected to using transverse stresses if he could possibly use direct stresses. If he could do without a beam or cantilever, and substitute for them parts subjected only to tension or compression, he would, as a matter of design, greatly prefer to use the latter. The Author had gone somewhat in that direction in his A frame for the beam-engines, but in a horizontal-engine it was no doubt possible to arrange the framing still more directly in the line of stress. Then, secondly, it was an important point of design to avoid as far as possible all important motions that were not essential to

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the actual work to be done. The vertical direct-acting engine fulfilled both these conditions, while on the other hand, the vertical beam-engine violated both of them, and it became a question whether it had such advantages as to counterbalance that violation. In the vertical beam-engine there was, of course, the swinging motion of the large mass of the beam, which had itself nothing directly to do with the actual motion of the engine, while at the same time the beam itself was subjected in almost every case to severe transverse stresses. The common idea that pistons of horizontal engines necessarily bore on the bottom of the cylinder, and wore it oval, seemed to him a mistake. If the piston-rod was strong enough to limit the deflection, the body of the piston itself would never actually bear on the cylinder, but only the spring-ring. If the piston-rod was too light, the body of the piston would jamb the spring-ring down hard, and of course, would grind the cylinder out; but that might be perfectly well avoided. If the piston-rod and piston were properly proportioned, the pressure on the cylinder walls ought to be simply that due to the spring-ring, and should be as uniform all round as in a vertical-engine. The inevitable wear on the piston-rod bushes was not so serious as to decide for or against a type of engine. On the other hand, it must be admitted that in point of accessibility horizontal-engines had considerable advantages over vertical ones, whether beam- or direct-acting. As to the matter of the relative friction in guides and in a parallel motion, he believed Dr. Pole many years ago discussed that question, and showed conclusively that the friction in the guides was not so excessively great, and especially not so much greater than that of a parallel motion, as had been generally supposed. He knew from his own working out of the matter, that the coefficient of friction in the guides had to be very large if a mean pressure of $1\frac{1}{2}$ lb. per square inch on the piston would not drive the crosshead along. The steam experiments showed no very distinctive advantage of one type over another. Probably no engines of any type had ever done better than those whose results Mr. Mair had quoted. But trustworthy experiments had shown that some horizontal engines worked down to so very small a consumption that he did not think it was possible to say at present that in steam consumption the one type had any definite advantage over the other. He remembered a remark of Mr. Edward Reynolds as to the beams of beam-engines, that he considered they ought to be made of very solid section, without considerable flanges, because he thought that the unused metal towards the neutral axis assisted

Professor Kennedy.

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Professor Kennedy. materially in preventing injury from sudden shock by helping the more strained metal outside. He should very much like to know the Author's opinion upon that point, or if he could give any practical data bearing upon it. Then as to the filling of the pump with water. It happened a few years ago that he had an arbitration in hand, in which it was necessary to measure the quantity of water discharged by large Cornish pumping-engines. The water was measured into a large brick tank, specially constructed, and he had an apparatus made by which he could measure and record the length of each individual stroke of the engine. He thus obtained the exact quantity of water which the pumps ought to have thrown, had they been working absolutely full, and certainly on one, if not more occasions, the pump threw 99 per cent. of this quantity—a result which he could only attribute to water slipping through the valve, on account of the valve not closing properly. In saying so much for horizontal-engines, he was very far from thinking that they left nothing to be desired. He wished, however, to supplement the Author's most vigorous statements on the other side by pointing out some things that might be said for them. It was a great point that continental engineers were practically unanimous in making horizontal-engines, for the Rouen beam-engines, mentioned by the Author, were made, either all or nearly all, by firms of English origin. The design of their engines was in every respect "Old English," but with a cut-off valve added.

Mr. Davey. Mr. H. Davey said the Author condemned the use of large horizontal-engines generally, and for pumping purposes in particular; his reasons being that the piston was liable to wear the cylinder oval, and that it was difficult to drain the cylinder of water. In short, horizontal engines were bad. Although he agreed with a great deal that the Author said in favour of vertical-engines for waterworks purposes; yet he did not consider it a necessary circumstance that a horizontal-engine should be less economical of fuel, or more subject to wear and tear than a vertical-engine. The circumstances of the application often rendered it necessary that a horizontal-engine should be used. If a horizontal-cylinder did wear oval, it was because the piston had not been provided with sufficient bearing-surface. At one time it was considered necessary to provide adjustment for wear on the slide-blocks of horizontal-engines; but the modern practice was to make the blocks with sufficient surface to prevent wear, and therefore requiring no adjustment. The piston was in a precisely similar condition. If its bearing surface was

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sufficiently large for its weight, it would not wear any more than it would in a vertical cylinder. It was a common thing to find horizontal-engines provided with tail-rods supported on slides to carry the piston; but in the majority of cases the tail-rod had no good effect whatever, except that it steadied the piston. It could not carry the piston nor even its own weight without sagging. In such engines the piston helped to carry the rod rather than the rod the piston. The proper method of preventing wear was to give surface enough. He had lately put up a 90-inch horizontal cylinder having a 10-feet stroke. The cylinder was bored in a horizontal position, and the piston made with a bearing-surface so large that a pressure of 6 lbs. per square inch was sufficient to support its weight. The bearing-surface, he took to be one-third the circumference. As regarded draining the cylinder, even when the valves were on the top, there was no difficulty. That could be done perfectly, without waste of steam, and automatically, by means of water-traps connected to the condenser. He quite appreciated what the Author had said about preventing bearings from knocking. In some vertical compound-engines which he had put up for waterworks purposes, he had so designed the engine that not only was the wear in one plane but in one direction only, so that even with slack bearings there was no knock. The strains on the beam were so distributed that the weight on any particular bearing was reduced to a minimum. The Author asked why continental engineers use horizontal-engines in preference to beam-engines for land purposes? The same question might be asked at home. Factory- and mill-owners and others thirty years ago put up beam-engines only; now they scarcely ever put up any but horizontal-engines. Returning to the question of draining the cylinder of water, the importance of that was emphasized by the Author's three diagrams, Figs. 9, 10, and 11. A glance at the diagrams demonstrated at once what was taking place, but it must not be hastily assumed that a large fall between the high- and the low-pressure cylinders was a fall which could be wholly remedied by the use of a steam-jacket, or a drain-cock. With such a late cut-off in the high-pressure cylinder, it was impossible to avoid a great fall in pressure between the two cylinders, and that was shown conclusively in diagram F, Fig. 32. In this it would be seen that where there was an early cut-off in the high-pressure cylinder, there was a very small fall in the pressure; where there was a later cut-off there was a larger gap. It might perhaps be said that was owing to Mr. Davey.

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Mr. Davey. the want of a steam-jacket. It was not entirely so. He never saw any steam-jacketed engine in which there was not a very great fall in pressure between the two cylinders when there was a late cut-off. Mr. Mair attributed the whole of the economy obtained in the jacketed cylinder to the jacket itself, but the diagrams convinced him that a very large amount of that economy was due to the earlier cut-off. The jacketed cylinder was worked with a cut-off of about one-fourth the stroke, and the unjacketed of about one-half the stroke, so that the economy was due not only to the jacket, but also to the earlier cut-off. For a proper comparison, the cut-off in the unjacketed cylinder ought to have been one-fourth. A compound engine working with so late a cut-off in the high-pressure cylinder as that shown on the diagrams, Figs. 9 and 10, must under the best circumstances have a larger fall in pressure below the two cylinders. The greater the degree of expansion effected in the high-pressure or hottest cylinder, consistent with obtaining a due proportion of power from the low-pressure cylinder, the less would be the condensation and consequent fall in pressure, and the greater the resultant economy. With condensation and re-evaporation taking place, there must be a loss of average pressure, because the steam was condensed at a high and re-evaporated at a low pressure; that was to say, the potential energy of the steam which had been condensed in the cylinder had been lost; the steam-jacket secured to a large extent that potential energy by partially preventing condensation. The economy of an engine could be judged from its indicator-diagram in this way: divide the average pressure by the terminal, and compare the quantity thus obtained with the theoretical value of the ratio of expansion, which ratio was expressed by dividing the initial pressure by the terminal pressure. He would take as an example the diagrams from the engine at the Lambeth Waterworks, which engine was provided with Mr. Cowper's superheating receiver, and had given a very high duty. He found from the diagrams that the initial pressure, divided by the terminal, gave 16·2, and the average pressure, divided by the terminal, gave 3·42. Now the theoretical value of expanding steam 16·2 times was expressed by adding one unit to the hyperbolic logarithm of 16·2. The actual value was expressed by dividing the average pressure by the terminal, which was in this case 3·42, or 90 per cent. of the theoretical. That 90 per cent. he would call the efficiency of the expansion, and an engine working with a great range of expansion and a high efficiency of expansion must necessarily be economical. Taking another example,

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Mr. Davey. the diagram G in Mr. Mair's experiments recorded in the Minutes of Proceedings of the Institution,[1] he found that engine was working with a range of expansion almost as great as the one to which he had just alluded, and yet its efficiency of expansion only amounted to 63 per cent., and as might be expected the engine was using over 20 lbs. of water per HP., whilst the engine with Mr. Cowper's superheater was only using 14·8 lbs. per hour. It was a noteworthy fact that the Cornish engine gave greater efficiency for a given range of expansion than any other kind of engine, and if the same range of expansion could be employed in it as was employed in modern compound engines, he believed it would give a higher duty; but that range of expansion was impracticable. The reason why the Cornish engine furnished a high duty for a given ratio of expansion was because the steam side of the piston was permanently isolated from the condenser. In fact, it might be regarded as a compound-engine in which the whole of the expansion was carried out in the first cylinder. Steam-jacketing had its beneficial effect for reasons which had been pointed out, but alone it was not sufficient to entirely prevent condensation in the cylinder. The full duty could not be got out of the steam without superheating. The economy of superheating had been proved over and over again, but practical difficulties had prevented its wide adoption. To his mind an ideal engine would be one with a superheater between the boiler and the high-pressure cylinder, and another superheater between the high- and low-pressure cylinders. Mr. Cowper had taught how practically to apply the latter, but a practical method was wanted of applying the former. It would then be economical to work engines with a greater range of expansion securing the economy due to perfect expansion. It must also be remembered that it was more important to prevent condensation in the first cylinder than in the second, because steam had the higher potential in the first cylinder. The greatest loss from condensation in the cylinder took place in the early part of the stroke, during and soon after the admission; therefore the great need of an efficient superheater between the boiler and engine. He had said that the Cornish engine gave a higher efficiency than any other class of engine for a given range of expansion, and he had been reminded that there were Cornish engines—the Prince engine at the East London Waterworks, with as low a consumption as 20 lbs. of water per HP. He did not know what expansion that engine was working

[1] Vol. lxx., Plate 11.

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Mr. Davey. with, but he imagined it was much the same as the Wicksteed engine, of which the total expansion was about four-and-a-half times, so that an engine working with 20 lbs., with four-and-a-half expansions, showed a remarkable result, and it bore out what he had said, that it was working with greater economy than any other engine with the same rate of expansion. There was no engine of any other kind working with such low consumption as that, with the same ratio of expansion. He was glad that the efficiency of the pumps, as well as of the engine, had been discussed, and that was a most important matter. It was very well to talk about the consumption of water or steam per I.HP., but the question above all others was the total cost of pumping water to a certain height, and that could only be arrived at by not only taking into consideration the efficiency of the boiler and engine, but also the efficiency of the pumps. Professor Kennedy had said that in a Cornish engine he got a pump efficiency of something like 99 per cent. That was unusual, but it was not uncommon to get 95 or 96. It was a most unusual thing to meet with a Cornish engine working with a slip of 3 or 4 per cent., but that could not be said of a rotative-engine working a short-stroke pump. To thoroughly thrash out this question engineers must go into the efficiency of the pumps, and find out the actual slip, and the exact quantity of water delivered; and in addition to that they must take the cost of repairs, the interest, and establishment-expenses, and balance the account. He thought in these days of scientific experiment they scarcely looked sufficiently at the commercial aspect of the question.

Mr. Mair. Mr. Mair explained that in order to get the same amount of power developed in the two cases of jacketed and unjacketed cylinders, the speed and boiler-pressure being the same, the steam must be carried further through the stroke, and therefore he might say to get 75·9 HP. in one case took 26·6, and to get 75·2 in the other only took 17·3 lbs. of steam.

Mr. Crampton. Mr. T. R. Crampton remarked that the late Mr. E. Humphrys, M. Inst. C.E., and he had made experiments, nearly forty years ago, with jacketed engines, using 40 lbs. of steam, with an effective expansion of about six times. They used 19 lbs. of water per HP. per hour. The engines were a pair of 40-HP. engines put up by Messrs. Rennie at Cubitt's building works. He mentioned this to show that the value of jackets and of expansion was known by some engineers at that time. When Mr. Wicksteed put up the engines which had been referred to, he had occasion to examine them, and he found that the weights of the moving parts enabled

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Mr. Crampton.

them to expand five or six times, and those engines gave velocities of piston at different parts of the stroke, practically the same as the crank engines. No doubt Cornish engines were the best, under certain circumstances. There was a way in which the horizontal pumping-engines could be adopted upon the Cornish principle, using them direct and double-acting, overcoming a large mass of matter, and utilizing the momentum during expansion, with only 40 lbs. of steam and four times expansion, as previously referred to. A consumption of 20 lbs. of steam per HP. per hour was all that was necessary; in fact it could be done with 16 lbs. of steam. He hardly believed in the great commercial value of excessive pressures and expansions. He believed that six times expansion for ordinary purposes, when properly carried out, was all that could be desired; the gain of twelve times expansion in practice was very small. A variety of losses occurred through the higher pressure, and thicker boilers, and a number of other difficulties had to be taken into account. The 20 per cent., which was all the gain theoretically, between six times expansion and twelve times, was lost in friction and numerous other causes, particularly in small engines. This he proved fifteen years ago by pumping water into a tank, when he found, over weeks of experiments, that by expanding six times and up to twelve times the diagrams came out sufficiently good. He got the 20 per cent. gain on the diagram, but he had no more water lifted into the tank than when he had six times expansion. As regarded the Cornish engine, by taking a simple horizontal engine, with or without a crank, and weighting sufficiently the reciprocating parts, the same good results could be obtained, as by the Cornish engine. This question was well worthy of consideration, at least he thought so.

Correspondence.

Mr. Donkin.

Mr. BRYAN DONKIN, Jun., stated that his firm had adopted steam-jackets for the last twenty years, and had made many experiments on the subject. He subjoined some notes of trials made on engines with and without steam in the jackets by various experimenters, and with different types and different-sized engines. The smaller the cylinder, the greater appeared to be their economical effect. Up to 36 inches in diameter, he preferred casting the jacket with the cylinder. The cylinders to be properly jacketed should be enveloped with the hottest steam, and not made so that any air

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Mr. Donkin. or water could lodge in them, as was too often the case. Hot air and smoke-jackets had been proved to be useless.

Compound engines certainly gave the most economical results, as compared with the single-cylinder type, particularly for regular work. He agreed with the Author that in many cases public local authorities were too much inclined to favour the cheapest machinery, without considering uneconomical working, as compared with a better class. Economical working was especially important in pumping-machinery in operation long hours. Where coal was cheap, near collieries, for instance, more was generally wasted in uneconomical engines and boilers, and in a greater ratio, than the lower cost of fuel at these places.

He preferred mill-engines of the horizontal compound condensing type, as the best for a permanent power. The foundations and fixing were inexpensive. As made by his firm, the weight of the pistons and rods was taken off the cylinders by an arrangement of Mr. Farey's.[1] This arrangement had been adopted for the last eighteen years. After seven or eight years' constant work night and day, the cylinders of several engines were very carefully gauged, and found not to have worn oval. The pressure could, in fact, be given upwards if desired. The system had been and still was applied to cylinders up to 3 feet in diameter with complete success. As an example of an economical performance of a pumping-engine, he would refer to that at the Barnet Waterworks.[2] The lbs. of feed-water or steam were 19½ per indicated HP. per hour, with a steam-pressure of 52 lbs. All details were given as to evaporation, effect of the coal in lbs. of water, the lbs. of steam per indicated HP., and the mean quantity of water pumped per indicated HP., and not simply lbs. of coal for so much water pumped, which of course had little scientific value as combining the several distinct questions of stoking, coals, boiler, engine, and pumps.

Notes on Experiments on Steam-Jackets.

Combe, 1843.—This French engineer seemed to have been one of the first to make a careful feed-water experiment. On a small condensing engine, with a cylinder 0·39 metre in diameter (15⅜ inches), the result was an economy in feed-water of 42 per cent., due to this cylinder being jacketed. Expansion was about 20 to 1; pressure of steam, 57 lbs.

John Farey, 1849.—In some experiments on a small beam condensing engine at Mr. Penn's flour mill, Lewisham, he said:—"Mr. Penn's comparative trials,

[1] Minutes of Proceedings Inst. C.E., vol. lxvi., p. 278. [2] *Ibid.*, p. 287.

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with and without steam in the steam-case, had shown the advantage of supplying steam around the cylinder to be very considerable." Steam pressure, 6 lbs. only. Mr. Donkin.

Hirn, about 1854.—This gentleman made some experiments on a compound condensing beam-engine, indicating about 104 HP. and 80 HP., with and without steam in the jacket, and found an economy in the feed-water of 24 per cent. in favour of using steam in the jacket. Steam-pressure, about four atmospheres; expansion, about 4 to 1.[1]

Mr. Gordon McKay, U.S.A., about 1858.—Non-condensing engine, steam pressure, 115 lbs., cylinder only 2 inches in diameter. Economy due to steam jacketing this cylinder, 20 per cent.[2]

B. Donkin and Co., 1859 *and* 1870.—With a compound condensing beam-engine, with cylinders 14 inches and 7½ inches in diameter, the economy due to jacketing these two cylinders was found to be 30 to 38 per cent. Feed water was measured. Steam pressure, 45 lbs.; expansion, 10 to 1. In two other experiments the expansion was kept the same, 9 to 1; steam-pressure 45 lbs. Temperature of condensing water was also kept the same, and the results were 24½ lbs. of steam required per I.HP. per hour with steam in the jackets, and 39½ lbs. with no steam in the jackets.

B. Donkin and Co., 1868.—On a 25 HP. compound condensing beam-engine, with cylinders $13\frac{3}{16}$ inches and 24 inches in diameter, the economy due to steam-jacketing both cylinders was found to be about 31 per cent. The results were 22½ lbs. of feed water per I.HP. per hour with both cylinders steam-jacketed, and 32⅝ lbs. with no steam in the jackets. Steam-pressure, 41 lbs.; expansion, 11 to 1 with jackets in use, 14 to 1 when not in use. Duration of trials, ten hours with and ten hours without steam in the jackets.[3]

B. Donkin and Co., 1869.—Single cylinder beam-engine, non-condensing. Cylinder, 7½ inches in diameter; economy of feed-water in jacketing this cylinder, 18 to 28 per cent.; pressure of steam, 45 lbs.; ¾ cut off, full steam and full steam throttled.[4]

B. Donkin and Co., 1870.—With a single-cylinder condensing beam-engine. Cylinder, 7½ inches in diameter. The economy due to steam-jacketing the cylinder was about 19 per cent. The feed-water was measured. Steam pressure, 45 lbs.; expansion, 2 to 1.

1871.—Large pumping-engine condensing single-cylinder. A gain of about 13 per cent. was found due to steam-jacket. Pressure of steam, about 35 lbs.

B. Donkin and Co., about 1872.—Compound condensing engine; steam-pressure, 40 lbs.; expansion, 4 to 1; economy due to steam-jackets, 25 per cent., indicating 140 HP. with jackets, and 90 HP. without.

1874.—A correspondent to "Engineering," after a trial, admitted an economy in favour of steam-jacketing large marine engines with cylinders 44 inches and 72 inches in diameter, of 15 per cent. Steam-pressure, 60 lbs.; expansion, about 5 to 1.

Hallauer, 1874.—Corliss single-cylinder condensing engine. Cylinder, 20 inches in diameter; pressure of steam, 73 lbs. Feed-water per absolute I.HP., 23·6 lbs. without steam in jacket, and 17·9 lbs. with.[5]

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[1] Bulletin de la Société de Mulhouse, No. 133, 1855.
[2] Journal of the Franklin Institute, 1859, vol. lxvii., p. 232.
[3] "Engineering," 15th May, 1874. [4] *Ibid.* 16th October, 1874.
[5] Bulletin de la Société de Mulhouse.

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Mr. Donkin. *U.S.A. Experiments about* 1874-5.—On engine of steamer "Bache." Compound Condensing. Cylinders, 16 inches and 25 inches in diameter; expansion, 6 to 1. Gain, 12 per cent. in favour of jacketing large cylinder only. Steam-pressure, 80 lbs. Each experiment lasted only two hours. Same engine, working with one cylinder (large one), gave about the same result, viz., 12 per cent. for jacket.[1]

B. Donkin and Co., 1875.—With a 6 HP. experimental compound condensing horizontal engine, with cylinders 6 inches and 10 inches in diameter; by applying steam to the jackets of both cylinders, there was found to be a decrease in the consumption of steam of 32 per cent.. Steam-pressure, 43 lbs.; expansion, 8 to 1.

Corliss Engine, 1878.—Single-cylinder condensing. Cylinder, 0·61 metre in diameter (24 inches). These experiments recorded a result in favour of jacketing the cylinder from 21 to 30 per cent.. Steam-pressure, 60 lbs.; expansion, about 6 to 1.[2]

Mr. Gower. Mr. C. F. Gower observed that two main considerations should be taken into account when designing engines for pumping, driving machinery, or other purposes. These were prime cost and working expenses. The first meant simply interest on capital, but the latter involved various considerations depending on the cost of fuel, the locality, wages, repairs, and the kind of duty to be performed. The Author was no doubt right, as a general principle, in giving the preference to engines with vertical cylinders, and the convenience of a beam for the attachment of pump-rods was, in the case of pumping-engines, undoubted. Nevertheless, reasons might be adduced for adopting the horizontal type of engine with advantage in many instances. The nature of the work to be performed, whether uniform and continuous or variable and intermittent, with a variety of other matters, must rule the design.

With large engines especially, every refinement, steam-jackets, compound cylinders, expansion valve-gear, &c., &c., that the skill of the engine-maker could suggest to economise steam, should be introduced; but with the smaller class of engines, liable to rough usage from untrained hands, these refinements were practically of little use. The proportion that the charge for wages bore to that for fuel, was, in the case of the smaller engines, much greater than with the larger types, and the class of men that had charge of them was less highly trained. Simplicity in the construction of the working parts was, in such cases, most desirable, economy in wages and repairs being, perhaps, as important as economy in fuel. The workmanship should nevertheless be of the best, of ample

[1] "Engineering," January 1, 1875.

[2] Bulletin de la Société de Mulhouse, 1878.

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strength, with good materials, &c., so as to reduce friction, wear and tear, with consequent repairs, to a minimum. Mr. Gower.

The steam used by the engine, might very properly be taken as the chief test of its efficiency; but the boiler was a necessary part of a steam engine, and must have due consideration. Economy of fuel as well as of steam was an object to be attained, and the boiler was consequently all important. Contracts were sometimes made for the engine, irrespective of the boiler, and perhaps also in the case of pumping-engines, irrespective of the pumps, the result being that the different parts thus ordered were not in the best way adapted to each other; the responsibility was divided among different contractors, and it was not surprising if the cost in working expenses turned out greater than it ought to have been. In all cases the word engine should include the boiler, and in the case of a pumping-engine, the pumps also. The maker of the engine should thoroughly understand the nature of the duty that would be required of it, and should have the opportunity afforded him of seeing, for his own credit's sake, that it did that duty in the best and most economical manner, not on a trial of a few days only, but in ordinary work.

Mr. Druitt Halpin remarked that beam-engines were occasionally built by German makers, for example, the compound-beam pumping-engines erected under the superintendence of Mr. Baldwin Latham, M. Inst. C.E., for the Danzig sewage works,[1] as well as the large pumping-engines built by Hartmann of Chemnitz for Krupp's pumping station at Bredenci, as well as the compound beam-engines at Breslau constructed by Mr. Schichau of Telbing. Mr. Halpin.

In answer to the Author's question, "Are modern Continental engineers right in adopting horizontal engines for nearly all land purposes? or is the Author right in advocating a much larger use than hitherto of vertical engines for land purposes, and using them almost invariably where large pumping power is required?" Mr. Halpin would observe that the two makers at Rouen who constructed the beam-engines shown at the Paris Exhibition of 1878, and referred to on p. 11, had now abandoned the exclusive use of beam engines, and were at present building horizontal engines as well, one maker building a single-crank tandem compound engine, with the air-pump behind, and the other maker an intermediate receiver compound horizontal engine, with cranks at right angles from Mr. Halpin's designs. With regard to the Author's statement that the refinement adopted by some Swiss and German

[1] "Engineering," 1870, vol. x., p. 85.

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Mr. Halpin. engineers of cambering the piston-rods, and thus making them transfer the weight of the pistons in horizontal engines from the bottoms of the cylinders to suitable bearing-surfaces on the cross-heads and tail blocks, had not yet been practised in this country, Mr. Halpin would refer him to the engines built by Messrs. Simpson & Co. of Pimlico, for Messrs. James Gibbs & Co., for their Plymouth works.[1]

Mr. Lightfoot. Mr. T. B. Lightfoot expected to find in the Paper some sort of detailed statement setting forth the good qualities of the various types of pumping-engine, so as to supply a means whereby an estimate of their respective values could be formed; but excepting for engines of small power he had been unable to find that any other type than the vertical had been credited with merit at all, except in the one single feature of first cost, which was admitted to be favourable to the horizontal engine. Then again there seemed to be a complete absence of all real data relating to first cost, consumption of fuel, and cost of maintenance, from which alone a useful comparison of the merits of different designs of engines could be made. The Paper, in fact, merely skirted the subject as regarded horizontal engines; but in his opinion was unduly elaborated as regarded engines made by the Author's firm, which apparently were essentially the same as those constructed by Mr. John Hall of Dartford, and others since the commencement of the present century. He did not, however, purpose supplying these omissions, for though he thought the objections to horizontal-cylinder engines had been very much overrated by the Author, he was so far with him, that he considered the vertical type was possessed of many decided advantages. But while admitting this, he did not pin his faith to the ordinary beam-engine, as he believed that in a great number of applications the inverted-cylinder direct-action engine would be found to have all its advantages, in addition to being less in first cost and occupying less space. If it was inconvenient to work the pumps direct, this class of engine might be used in connection with a beam or quadrant, or with gearing, while still keeping the cost of the installation below that of the old-fashioned beam-engine, and as the fly-wheel was directly attached to the piston by a single connecting rod, the beam was relieved from the excessive stress due to the high initial pressure of steam, and was merely subjected to the almost uniform pull and thrust of the pump-rods. With regard to the material for constructing the beams, he took

[1] "Engineering," 1879, vol. xxvii, p 422.

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Mr. Lightfoot.

the very opposite view to that advanced by the Author. He considered that, excepting perhaps for very small engines, cast-iron should be entirely discarded in favour of wrought-iron. He thought also that the use of cast-iron for connecting-rods and cranks, as was shown on some of the Author's drawings, was much to be deprecated. Years ago, before the introduction of steam-hammers, engineers were compelled to make the heavy parts of their engines of cast-iron, and no doubt with the excellent material and comparatively low steam-pressures then used, cast-iron answered the purpose fairly well. This, however, was not the case at present. Wrought-iron plates and forgings of almost any size could be produced with facility, and when cast-iron was used it always seemed to him as if modern engineers in copying the general design of the old Woolf engine had also copied its antiquated details, instead of bringing them up to the present level of engineering construction. He had found that breakages of cast-iron beams, connecting-rods, and cranks, were not at all of uncommon occurrence, and he felt sure that many engineers must have had a similar experience. Of course the Author might say that such accidents would not have happened if the parts had been properly constructed, and no doubt this was to some extent true. But to choose for the vital parts of large engines, a comparatively brittle material of low strength liable to hidden flaws, when, on the other hand, at a slightly increased expense, a stronger material could be procured, which, with less care in manufacture, gave much more certain results, was, to say the least, not very good engineering, and was to his mind sacrificing a certainty for an uncertainty for the sake of a small saving in first cost. With regard to beams of rotating engines, it was often stated, and had been stated during the present discussion, that it was of great importance to have the weight given by the use of cast-iron, in order that it might act as a regulator to store up the excess energy developed at the commencement of the stroke, and give it off to the pumps towards the end, when, by expansion, the steam-pressure had become much reduced. In Cornish engines, no doubt this was so; but in rotatory engines with fly-wheels, he submitted that no such action existed except to a very limited extent, for the velocity of the beam was so exceedingly low that it was incapable of acquiring much additional energy without a great increase to its speed. Owing to the angularity of the crank, however, this increase could not be attained without a much larger acceleration in the velocity of the fly-wheel, the rim of which already travelling at a comparatively high velocity, was capable of taking up a considerable amount of energy with a small

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Mr. Lightfoot. increase of speed almost imperceptible on the beam. He therefore maintained that in rotatory beam-engines of ordinary construction the equalization of speed was chiefly accomplished by the fly-wheel, and he believed this to be not only what actually did take place, but he thought it was what was to be desired in order to avoid the jerky motion and variation in speed so observable in Cornish engines. If weight was wanted, the fly-wheel rim was the place to put it, and proper regulation could generally be obtained with a comparatively light wheel, the best plan for ascertaining the weight of rim being to first of all fix the limits of deviation of speed, and then to lay down a diagram of combined tangential efforts and resistances, from which the variation in energy could be measured to any convenient scale, and from this the necessary weight could be at once calculated.

Apart from this question altogether, he had never found much difference between the weights of cast- and wrought-iron beams if properly constructed. He had made a considerable number of all sizes, large and small, and did not think that cast-beams could be averaged at more than from 10 to 20 per cent. heavier than wrought-iron ones. It had been urged against wrought-iron beams that they were springy, and that the gudgeons were liable to work loose. When they were badly designed this might be so; but he had never found it, and the only defect which had come under his notice was, in the case of two or three built-up beams, made before the proper proportioning of rivet and other bearing surfaces was fully appreciated, in which there was a creaking sound at each stroke of the engine, due no doubt to a slight movement of the plates. He might, perhaps, mention that about ten years ago he designed a wrought-iron beam for a Cornish pumping-engine for the Hull Corporation Waterworks, which he believed was the largest example of the kind in this country. Its length was 40 feet from centre to centre, and greatest depth 8 feet. It weighed a little over 40 tons, or within 7 tons of the estimated weight of a cast-iron beam. It had been almost constantly at work since 1876, and was quite stiff and satisfactory in every respect; indeed the Corporation Waterworks engineer had recently told him it was a perfect piece of work. The steam piston of the engine was 96 inches in diameter, and the length of stroke 12 feet. His opinion as to material was so strong in this case that he declined to have anything to do with the work unless he was permitted to make the beam of wrought-iron, notwithstanding there was considerable feeling against its use on the part of some of the officials then interested in the matter.

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Mr. G. W. Sutcliffe remarked that the vertical position was almost invariably the correct one for the axis of a cylinder, and if the design of the steam-engine ever arrived at a state of stable equilibrium, it would probably be found that for ordinary rotary driving or pumping-gases, the inverted direct-acting type would be adopted, while for direct pumping of heavy liquids the beam-engine would be most successful, with in each case few exceptions. Many horizontal engines were, however, to be found which give little trouble in wear, and worked most smoothly with only one joint in the main brasses, this result being promoted by the existence of heavy fly-wheels; though the shaft might not fill the brasses, no trouble was caused when proper attention was paid. Mr. Sutcliffe.

For purposes where several pumps were required to be worked, the beam-engine possessed advantages which must be freely admitted; but for compactness and diminished cost, the vertical inverted engine might be adopted. This could be arranged with a parallel motion as easily as a beam-engine, and only required to be properly proportioned to be effective. Some direct-acting vertical and many horizontal engines for ordinary driving had been built with parallel motion many years and worked well, and the application to pumping purposes was obvious. The point of importance in this connection was that the joints should be not easily tampered with, so as to disturb the centres and lengths of rods.

It was almost impossible to attach too much importance to the necessity for preserving exact symmetry in the framing of a vertical inverted engine, taking the co-ordinate planes through the piston-rod as bases. If this was not done it was impossible to make a good firm job, while in the opposite case a very different result was arrived at. In 1876 there was a vertical inverted pumping-engine at work at Providence, R.I., in which one frame carried one overhanging cylinder at each side,[1] and few modern engines could be found to sway about more freely in work. In the same house there was a horizontal engine by Mr. Corliss, with five cylinders and five pump barrels arranged radially around one vertical crank-shaft; at the time in question the latter engine was standing, but reports as to steadiness and mechanical efficiency were most assuring. Doubtless the latter was an extravagant arrangement; but if the merits of vertical and horizontal engines were to be decided upon these results, it would be most unfortunate.

In the framing of marine engines more attention was now paid

[1] The "Engineer," 1876, vol. xlii., p. 323.

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Mr. Sutcliffe. to symmetrical arrangement than formerly, and it was believed with good results. So many points of difference arose, that it was difficult to estimate the exact effect of the change in frame, but if two new engines were to be found exactly alike in design and workmanship, with the exception of the frames, the comparison of their working steadiness would be very instructive.

In the Paper the use of the term D valve was rather unfortunate, as obviously, from the context, an ordinary short single-ported slide-valve was referred to, and the term D valve might with advantage be confined to the original pattern, which was formerly fitted to side-lever and other low-pressure engines.

The condemnation which the Author bestowed upon the horizontal engine must be confirmed by the results of general experience, though it was to be applied with feelings of regret to large numbers of engines, which, being excellent in their horizontal form, would be doubly so if the cylinder stood over the crank-shaft. This would almost necessitate a departure from four diameters in length of stroke, after which the wonder would arise why this had not been done long ago.

Mr. Wheeler. Mr. W. H. Wheeler stated that a great number of engines were in use in the Fens on the east coast for pumping the water off the low lands into the rivers. The lift of the water in these cases was small, varying from 4 feet to 10 or 11, and up to 15 or 16 feet as a maximum. The work was very intermittent, the engines only being in use during the winter and wet weather, and frequently lying idle for the greater part of the year. Before the use of steam-power the drainage was effected by wind-mills; the introduction of steam-power commenced about sixty years ago. The engines then introduced were beam-engines of a massive character, and working at a pressure of about 5 lbs., the steam being condensed by jet-condensers. Two of the largest of these engines were at Podehale, near Spalding, used for the drainage of 30,000 acres of land in Deeping Fen, one being 80 HP. and the other 60 HP., driving scoop-wheels 31 feet and 28 feet in diameter, and lifting together about 14,900 cubic feet a minute. The velocity of the wheels at the circumference was from 5 to 6 feet a second. The next largest scoop-wheel was that on the Hundred-feet River for the drainage of the Lilleport and Downham district in the Bedford Level. This wheel was 50 feet in diameter, and was driven by a condensing beam-engine of 80 HP. The average height the water was raised being about 15 feet. Other engines varied according to the size of the districts, some being as small as 8 or 10 HP. These beam-engines were probably as well or better adapted than

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Mr. Wheeler.

any other kind at the time they were erected for driving the ponderous pumping-machines at the low speed at which the scoop-wheels revolved. The scoop-wheels were now, however, being superseded by centrifugal pumps. Taking into consideration the speed at which these were driven, the expense of foundations and cost of condensing steam-engines, experience was in favour of using engines of a simpler or less costly construction. Simplicity and fewness of parts were also desirable on account of the class of men employed to drive these drainage-engines. The engine-drivers are generally drawn from the men employed with the portable engines used for thrashing machines. These men had never served their time as fitters or enginemen, and knew little or nothing about the construction. For these reasons a single-cylinder engine, or in large districts a pair of cylinders, working at an initial pressure of about 60 lbs., and cutting off the steam at one-third of the stroke, was the machine that appeared the best adapted for the purpose. The first cost of such an engine was small, and the amount of foundations required was less than for any other description, an important item in districts where stability could only be procured by piling. The saving of coals by the use of condensing beam-engines would no doubt form a considerable item in the course of a year for a large engine constantly at work, and would under such circumstances more than counterbalance the extra cost of repairs, interest and depreciation; but when an engine was only used for a period of the year, and had to be driven by a more or less unskilled engineman, the saving would be more than swallowed up by the cost of repairs and interest on first outlay. For driving pumps for the drainage of land, the simplest construction of vertical or horizontal high-pressure non-condensing engine was preferable to the rotative condensing beam-engines.

Mr. Rich.

Mr. Rich, in reply to the discussion, both oral and written, desired in the first place to express his acknowledgments to those who, by friendly criticism, had contributed much valuable information on many of the points raised in the Paper. His object had been to compare vertical and horizontal engines generally, and to direct attention to the advantages of beam-engines for pumping, chiefly in relation to the mechanical questions involved. He had purposely avoided giving lengthy descriptions of engine trials and of economical performances, as these were to a great extent independent questions requiring separate treatment and discussion. The statistics in the Paper were chiefly intended to show in a marked manner the uselessness of material expansion in unjacketed

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Mr. Rich. cylinders, and the great importance of steam-jacketing in compound engines when high economy was desired. No one probably appreciated the value of steam-jacketing more than he did, as a disciple and a thorough believer in the principles of the late Professor Rankine. He had taken a leading part in the trials at Cardiff, where it was apparent that even the small single-cylinder high-pressure engines had no chance of success unless they were furnished with efficient steam-jackets; and as the results of experience in testing a large number of engines of various kinds he could state that a high economy had never been obtained without them. At the same time purchasers and users of steam-engines frequently did not appreciate the advantages to be derived from them, and from some other apparatus which tended to economy, and would not incur the extra cost; and even when steam-jackets were supplied, they were too often tended by engine-drivers, who, from ignorance or negligence, failed to realize the possible advantages. Indeed, from personal observation, he believed that not even one-half of the steam-jackets in existence were worked efficiently. Evidently Mr. Gower and Mr. Wheeler shared this opinion. Since the Paper was read a compound-beam pumping-engine had been ordered by clients who preferred having it, without steam-jackets, like two old engines which had worked well for many years, though strongly urged to have steam-jackets. The thanks of the Institution were eminently due to Mr. Donkin for his valuable series of records regarding steam-jackets. Mr. Mair's experiments on the effect of shutting off steam-jackets were also very important. The performances of the Lambeth engines alluded to in the Paper were by no means cited as the best of which those engines and of others also mentioned were capable. In the first trial the Lambeth engines were working against a lift 40 per cent. in excess of their normal duty; in the second case one pair had been working eighteen months, and in the other five months. No examination or overhaul of pistons or valves had been made previous to the trials; and as the results showed that the engines were doing considerably more than their guaranteed duty, there was no object for delaying the operations at the pumping stations to take such extra precautions.

The term steam-consumption, which he had used, was perhaps a misnomer, as it included the weights of all the water-particles primed over with the steam from the boilers, and the condensation in a long range of main steam-pipes with several branches. The results were therefore not comparable with those given by Mr. Mair and by Mr. Cowper, from which these important items had

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been deducted. Doubts had been raised by Mr. Mair as to the mechanical efficiencies given by him, which in the extended trials of the Lambeth engines showed 0·905, 0·901, and 0·896 respectively, on the assumption that the pumps in those cases were discharging to their full capacities. Unfortunately no facilities could be given at the Brixton station at the time of the trials for measuring the pump discharges; but he had every reason to believe that the figures were within 1 per cent. of the truth, as from the construction of the pumps there could not possibly be any lodgment of air between the valves. The bucket-packings and valves were practically in perfect order, and watertight; the valves had very low lifts, and so closed without losses at the ends of the strokes; and several indicator-diagrams taken from the pumps confirmed his views to a great extent, by the absence from them of rounded corners, and the evidences of steady discharge throughout each stroke. These engines were in several respects inferior to some more recently constructed; but he believed that if they were tested after a fair overhaul by a thoroughly independent and unprejudiced engineer, they would compare favourably, in their steam-consumption per effective HP. in water lifted, with any other engines in the Metropolitan district similarly tested, including of course those referred to by Mr. Cowper and by Mr. Mair. He was satisfied the members generally would be as much gratified as he was, that the Paper had elicited from Mr. Mair such an important contribution respecting the designs of various pumping-engines, accompanied by indicator diagrams and statistics of performances. Mr. Rich.

As to the question of the advantage of heavy beams or pistons in pumping-engines, for absorbing work at the commencement of the stroke and giving it out again at the end, he agreed with Mr. Lightfoot that such weight might be of considerable value in Cornish, and in highly expansive single-cylinder rotative, pumping-engines; but that they could be of no practical importance in compound rotative Woolf engines. Nevertheless, he considered unnecessary weight in working parts prejudicial in many ways. Various opinions had been expressed regarding the comparative merits of cast-iron and of wrought-iron for engine-beams. Mr. Lightfoot had mentioned a case of a colossal beam, in which wrought-iron had been adopted; but a majority of the speakers evidently believed with Mr. Rich that cast-iron was the better metal for beams of all ordinary dimensions. He commended the mixture of metal mentioned to the notice of engineers requiring large tough castings. From his own experience he was able to

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Mr. Rich. confirm Mr. Lightfoot's remark, that there was very little difference in the weights of cast-iron or of wrought-iron beams of the same strength.

His opinion had been asked by Professor Kennedy whether a thick centre web to a beam was beneficial for preventing injury from sudden shock, by helping the more strained metal outside. It was an interesting point, but one to which he had hitherto given no attention. In engine-beams, as in all large castings, it was of the utmost importance that internal corners should be well rounded, and that variations of thickness should be very gradual.

On the question of the support of pistons in horizontal engines, opinions differed considerably. Mr. Davey and Mr. Walker contemplated large piston-surfaces only; Professor Kennedy advocated a small piston with a thick rod well supported on end girders, the weight and pressure of the piston-spring rings only being supported by the cylinder. Mr. Schönheyder was the champion for the bent rod; and Mr. Rich by no means desired to cast discredit on a very ingenious arrangement. He would, however, object to an excess camber in a new engine causing extra pressure upwards, as the top of a horizontal-engine cylinder was the most difficult to keep lubricated.

The remarks of Mr. Schönheyder on long suction-pipes touched a subject which was deserving of special attention. He believed a great deal of valuable information would be obtained regarding this matter, and the working of pumps and their valves generally, if indicator diagrams were taken more frequently from pumps under various conditions.

He was glad to find that Mr. Cowper claimed the introduction of surface-condensers in pumping-engines, in which the service water was the cooling-agent. Such condensers had been used with great advantage in several recent engines; and as these condensers involved a reduction in the size of air-pump, and an avoidance of injection-pipes and cocks and sometimes of a cold-water pump, they added but little to the total first cost. They were especially valuable when the water raised was too hard for convenient use in the pumping-station boilers; and as the temperature of the water was only raised about 1° per 100-feet of lift in good engines, no practical harm was done in that way.

The remark of Mr. Walker on the floating of a journal on a film of the lubricant, so that no metallic contact ever took place, was no doubt what should be aimed at; but engine-constructors had not yet arrived at such perfect fitting as to admit of reliance on such action, and it was indisputable that practically some wear

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must take place in course of time in all bearings. Mr. Davey had spoken of his practice of introducing automatic water-traps between the horizontal engine cylinder and the condenser; such an arrangement would frequently be very valuable if properly applied. Mr. Rich.

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29 April, 1884.

Sir J. W. BAZALGETTE, C.B., President,
in the Chair.

The discussion upon the Paper by Mr. Rich, "On the Comparative Merits of Vertical and Horizontal Engines, and on Rotative Beam-Engines for Pumping," occupied the evening.

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6 May, 1884.

Sir J. W. BAZALGETTE, C.B., President, in the Chair.

The following Associate Members have been transferred to the class of

Members.

Edward Brailsford Bright.
William Evill.
Thomas Matthews.

The following Candidates have been admitted as

Students.

Llewelyn Birchall Atkinson.
Joseph Percy Clarke.
Charles James Croft.
John Dunn Ferguson.
Matthew Garbutt.
Alfred Holden.
Nicholas Paul Jasper.
David John Lavelle.
Edward Howis Marston.
Henry Martyn Phillipps.
John Platt.
Bertram Adams Raves.
Charles Liddell Simpson.
William Stringfellow.
Albert Westlake.

The following Candidates have been balloted for and duly elected as

Members.

James Young Davidson.
William Davies.
Percy Carlyle Gilchrist.
William Knox Laurence.
Edward Pritchard.
John Henry Ryan, B.A.
Coleman Sellers.
Beauchamp Tower.
John West.

Associate Members.

Alfred Dyke Acland, Stud. Inst. C.E.
Percy Baylis, Stud. Inst. C.E.
William Brereton Bestic, Stud. Inst. C.E.
John Hope Callcott.
Ernest Collins.
Eben Connal.
Henry Streatfeild Cotton, Stud. Inst. C.E.
Adolpho José Del Vecchio.
Edward Dukinfield Jones.
Allan Ferguson Joseph.
Albertus Philippus Kapteyn.
Andrés Llobet.
Arthur Charles McMinn.
Martin Mildred, Stud. Inst. C.E.
Philip Henry Palmer.
Henry Richard Clarke Pauling.
Frederick Carrington Phillips.
David Alan Stevenson, B.Sc.
Charles Jerome Tisdall, B.A.
Alexander Wilson.

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(*Paper No. 1986.*)

"On the Antiseptic Treatment of Timber."

By Samuel Bagster Boulton, Assoc. Inst. C.E.

In January, 1853, a Paper upon Timber Preserving was contributed to this Institution by the Author's partner, the late Mr. Henry Potter Burt, Assoc. Inst. C.E.[1] (6) (20). Since that date, the use of Antiseptics for the treatment of timber has largely increased, and is year by year increasing. For engineering purposes, the process called Creosoting, which consists in the injection of the coal-tar oils, has in this kingdom entirely, and in other countries to a very considerable extent, displaced the other well known methods.

Concurrently with this development, a series of remarkable discoveries in chemical science has raised the manufactures connected with the residual products of gas-making to a position of great and growing importance.

It is proposed in the present Paper, to give a short account of the history and development of the use of antiseptics for preventing the decay of timber. A reference to the processes employed in coal-tar distillation will be pertinent to the subject, in so far as it will indicate what are and have been the usual constituents of the tar oils used for injecting wood. The Author proposes to add some results derived from his thirty-four years' experience in connection with this group of manufactures, together with the outcome of some research, and of a number of experiments specially undertaken with a view to the elucidation of questions referred to in the Paper.

Early History of Timber Preserving.

Timber was naturally the first material employed by man for the purposes of constructive engineering. If it be true that the first models of Grecian architecture were copied from, and retained

[1] The numbers in parentheses refer to various authorities, Appendix No. 4.

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some of the distinctive features of, buildings in wood, then may still be seen recorded, upon the columns of the five great orders of architecture, proofs that the Greeks or their precursors took special expedients to preserve timber from decay. The wooden pillar was placed upon a block of stone to preserve it from the humidity of the soil, and it was covered at the top by a slab or tile to throw off the rain. These contrivances are supposed to have been copied in the base and capital of the column, when wood came to be replaced by stone. Scamozzi imagines also, that the mouldings represent metal hoops, placed around the wooden pillars to prevent them from splitting.

Allusions to various substances employed for preserving timber and other vegetable fibres from decay, are frequent in the writings of the ancients. Tar and pitch were used for painting or smearing wood from periods of the most remote antiquity. Greek and Roman authors narrate, that the astringent portions of the oil expressed from olives (Amurca 16), (70) also oils derived from the Cedar, the Larch, the Juniper and the Nard-Bush (Valeriana) (70) were used for the preservation of articles of value from decay, or from the attacks of insects. The magnificent statue of Zeus by Phidias was erected in a grove at Olympus where the atmosphere was damp; the wooden platform upon which it stood was therefore imbued with oil. The famous statue of Diana at Ephesus was of wood. If its origin was believed to be miraculous, no standing miracle was relied on for its preservation. Pliny asserts upon the authority of an eye-witness, Mucianus, that it was kept saturated with oil of Nard by means of a number of small orifices bored in the woodwork (71). The same author remarks that wood well rubbed with oil of Cedar, is proof against wood-worm and decay (71). The art of extracting and preparing oils, resins, tar and pitch from various trees and plants, and from mineral deposits, is mentioned by Herodotus (41), and at great length by Pliny. This last author describes in detail, the manufacture of no less than forty-eight different kinds of oils (72) (73). Of the employment of the oxides or salts of metals by the ancients for wood preserving, there is no direct evidence.

Egyptian Mummies.

Of all the methods employed by mankind for the artificial preservation of organized substances, there are perhaps none which have equalled in success the processes of the ancient Egyptians.

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The durable results of these processes are amazing, and although the topic is a hackneyed one, it is nevertheless inseparably connected with the subject of this Paper. The descriptions by contemporary writers of the Egyptian art of embalming the dead are somewhat conflicting; moreover they do not adequately explain the appearances presented by many of the mummies themselves. The bodies are said to have been imbued, either with resinous or odoriferous gums, or more frequently with bitumen or with oil of cedar, or commonly with natrum, and often with several of these substances in succession. So far, these statements are confirmed by modern investigation. By reading Herodotus (42) and Diodorus Siculus (35), however, it would perhaps seem that the body was first steeped in the natrum for seventy days, and then subjected to the oily, or bituminous preparation. In other places it might be gathered that the oily preparation came first, and the steeping in natrum afterwards. Without further explanation, neither of these processes would appear to be practicable. At ordinary temperatures, the steeping in the one preparation would interfere with the absorption of the other. Natrum is supposed to have been a natural substance, obtained from some briny lakes, still existing in the neighbourhood of Cairo, and consisting principally of a mixture of sodium-sesqui-carbonate, sodium-chloride and sodium-sulphate (57), (65). Rouyer, who accompanied the army of Napoleon to Egypt in 1798, expressed his conviction that the mummies had been placed in ovens in order to eliminate moisture, and to facilitate the penetration of the bitumen (33), (66), (77). But no ancient author mentions any such process, nor is there any record of it amongst the numerous and detailed pictorial representations which have been discovered in tombs and temples.

Pettigrew, in his valuable work on this subject, whilst giving the results of his examination of various mummies, and of analyses of embalming materials (69), expresses his opinion that the bodies must have been subjected to a very considerable degree of heat, as even the inmost structure of the bones is penetrated by the antiseptics (67). By some it has been supposed that this was effected by steeping the body in a cauldron of heated bitumen. Pettigrew's most striking experiment was made with the heart of a mummy, from which he succeeded in withdrawing by maceration the preservative substances, when, after 3,000 years of perfect preservation, the heart began at once to putrefy (68). This is a striking proof, both of the efficacy of the substances employed, and also of the fact, that the immunity from decay was not due to a

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chemical transformation produced once for all, but that it depended upon the abiding presence of the antiseptic. In recent anatomical practice, carbolic acid has been used for injecting bodies for purposes of dissection. When this is done, however, it is found necessary to renew the process after the lapse of a few weeks, a contrast to the antiseptics employed by the Egyptians (92). Pettigrew's description showed that the worst preserved of the mummies are those prepared with natrum alone, the most perfect being those in which solid resins or bitumens remain incorporated. Natrum is frequently found accompanying the bitumen in some of the most successfully preserved specimens. It is probable that some astringent or other substances were also used, the secret of which has hitherto eluded modern investigation.

The Author has caused some experiments to be made with pieces of timber, in order to test a theory which suggested itself to his mind. The wood was first thoroughly impregnated with a mixed solution of the three salts of sodium of which the natrum brine is composed. Afterwards the wood was steeped in tar oil, heated to 230° Fahrenheit. The heat of the tar oil volatilized the water of the soda solution, and the oil took the place of the water. The timber remained impregnated with the saline particles, and saturated with the tar oil. May not this have been the method used by the Egyptians to impregnate both with natrum and oils?

There is no doubt that the ancients had, by observation and experience, acquired considerable practical knowledge of antiseptic substances. They were also of opinion that those woods lasted the longest which were most odoriferous, or, in other words, those which contained the greatest quantity of resin (74). They knew that timber continually kept under water was less liable to decay than when exposed to the atmosphere (75). They observed the ravages of the *Teredo navalis* upon timber placed in the sea (76). But it is useless to seek amongst the writings of the elder Classics for any reasonable theory in explanation of these phenomena.

Growth of theories upon the causes of Putrefaction.—It is not until the eighteenth century of the present era that anything beyond the merest trace can be detected of serious analytical research into the causes of decomposition. After the fanciful dreams of the alchemists had been dissipated, the more solid portion of their labours, facts arrived at in the course of their experiments, remained for the uses of science. Investigations were undertaken respecting the phenomena of fermentation and of putrefaction, animal and vegetable. It was at one time declared, that putrefaction was due to the escape of an element called phlogiston, an

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imaginary substance which was believed in by such eminent chemists as Scheele, the discoverer of chlorine, and Dr. Priestley, the discoverer of oxygen. Later on Dr. Macbride propounded a theory that carbonic acid gas had a special power of promoting cohesion, and that putrefaction was due to its being given off (37). None of these theories explained why putrefaction did not attack the tissues until after the vital movement had ceased. By the commencement of the present century, however, it began to be generally believed that the putrefaction, at least of vegetable matter, was a species of fermentation, although it was not admitted that ferments of any kind were the products of living organisms. Little by little the similarity of the natural processes connected with the fermentation of alimentary substances, the decay of vegetable tissues, and the putrefaction of the bodies of animals began to be recognised; and, to the great advantage of scientific progress, these three classes of phenomena have ever since been studied in close connection with each other.

In the meantime practice stole a march upon theory. About the year 1770 Sir John Pringle published a list of antiseptics, in which example he was followed by Dr. Macbride (38). Many of the substances proposed by these and other theorists, particularly the alkaline bodies, are absolutely injurious to timber. But towards the close of the last century and at the beginning of the present, experiment was greatly stimulated by the wants of the British navy. During the colossal struggles of Great Britain with hosts of adversaries, the very existence of the nation appeared to be staked upon her fleets. The great prevalence of dry-rot in the timbers of British men-of-war assumed the proportions of a national calamity. It was said that a single 70-gun ship required for its construction the oak of 40 acres of forest, and that the supply would fail. It was in 1812 that Lukin tried, in the Woolwich Dockyard, his disastrous experiment with the injection of resinous vapours (39). More practical suggestions were soon forthcoming, and the use of the salts of various metals began to be recommended. Sir Humphrey Davy suggested corrosive sublimate; Thomas Wade (in 1815), the salts of copper, iron, and zinc (39). The opinion gained ground that poisons of various kinds were correctives to the decay of timber.

From the year 1768 up to the present time, the records of the Patent Office contain lists of almost every conceivable antiseptic, suitable or unsuitable, for the preservation of wood.

Progress during the Railway Era.—But it is since the birth and growth of the railway system, that the antiseptic treatment of

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timber may be said to have received its most important development. The stone blocks and other solid supports, at first used for the permanent way of railways, were found to be too rigid, and had to be replaced by a more elastic material. The wooden sleepers which were substituted decayed so rapidly, that some artificial method for prolonging their duration began to be considered as an engineering necessity. By the year 1838 four several systems of antiseptic treatment were fairly before the public, and competing for the favour of engineers. These were: Corrosive sublimate, introduced by Mr. J. H. Kyan; sulphate of copper, by Mr. J. J. Lloyd Margary; chloride of zinc, by Sir William Burnett; heavy oil of tar (afterwards called creosote), by Mr. John Bethell.

Corrosive sublimate, or bi-chloride of mercury, was successfully used by Homberg, a French savant, in 1705, for preserving wood from insects. It was recommended by De Boissieu in 1767. In 1730, the Dutch Government tried it upon wood immersed in sea-water as a remedy against the *Teredo navalis*, but for this purpose it failed (58). In the "Encyclopædia Britannica," in 1824, it is recorded that Sir Humphrey Davy recommends its use for timber (39). Kyan's first patent, for the employment of corrosive sublimate for wood-preserving was taken out in 1832 (43). His first success was gained by the preservation of the woodwork of the Duke of Devonshire's conservatories. Kyanizing was for a long time by far the most popular of the timber-preserving processes in this country, and the name is to this day frequently applied erroneously to other systems. Used in sea-water, however, by the British Admiralty, this process turned out a failure, as it had done under similar circumstances with the Dutch Government a century earlier. Kyanizing has met with a considerable amount of success in comparatively dry situations; but in water, and particularly in sea-water, it appears to have invariably failed, as have all the salts of metals. Corrosive sublimate is somewhat volatile at ordinary temperatures; it also has the drawback of producing injurious effects upon the workmen employed in handling it.

Sulphate of Copper.—The use of this and of other salts of copper was recommended by De Boissieu and by Bordenave in 1767 (59), and by Thomas Wade in 1815 (39). In 1837 Mr. Margary took out a patent for the use of sulphate and acetate of copper (48). Sulphate of copper has perhaps been the most successful of all the metallic salts as an antiseptic for timber. Applied in various ways it was popular in France long after it had been

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given up in this country. It is still in use in France to a limited extent, for sleepers and telegraph poles.

Chloride of Zinc.—This was recommended by Thomas Wade in 1815 (39), and by Dr. Boucherie in 1837 (60); and a patent for its application was taken out in this country by Sir William Burnett in 1838 (9). The process of Burnettizing was at one time much patronised by the British Admiralty. For railway sleepers it was extensively adopted in France by the Author's firm, principally on the railways from Orléans to Bordeaux, and from Caen to Cherbourg. It is no longer used in France, but it is still employed in Holland and in Germany. Chloride of zinc is a powerful antiseptic, but its weak point for wood-preserving consists in its extreme solubility in water.

Heavy Oils of Tar, commonly called Creosote.—As early as 1756 attempts were made both in England and in America, as described by Knowles, to inject or impregnate timber with vegetable tars or with extracts therefrom. The first mention of the products of the distillation of gas-tar, to be used separately for impregnating timber, appears to be by Franz Moll. This inventor took out a patent in 1836 (49) for injecting wood in closed iron vessels with the oils of coal-tar first in a state of vapour, and next with the heated oils in the ordinary liquid state. He recommended the adoption both of the oils lighter than water, and of the oils heavier than water, calling the former "Eupion" and the latter "Kreosot." He relied upon the Kreosot for its antiseptic qualities, but proposed to use the light oils separately, at the commencement of the operation, for the purpose of facilitating the absorption of the heavy oil. This plan has never been acted upon, as it would be obviously wasteful and unpractical to inject the lighter oils, or crude naphthas, which would immediately evaporate.

The practical introduction of the process is due to Mr. John Bethell. His now celebrated patent, which is dated July 1838 (3), does not mention the words "Creosote" or "Creosoting." It contains a list of no less than eighteen various substances, mixtures or solutions, oleaginous, bituminous, and of metallic salts. Amongst them is mentioned a mixture consisting of coal-tar thinned with from one-third to one-half of its quantity of dead oil distilled from coal-tar. This is the origin of the so-called Creosoting process. Creosote, correctly so called, is the product of the destructive distillation of wood, and coal-tar does not contain any of the true Creosote, which has never been used for timber preserving. But a substance, since called carbolic acid, or phenol, had been discovered in coal-tar; it was thought by some to be identical with the

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Creosote of wood, hence the process came to be miscalled, after a time, the Creosoting process. It is in this popular sense only that the word Creosote is to be understood in the remainder of this Paper. The two substances, Creosote and Carbolic acid, are described and contrasted, and their varying properties delineated in Dr. Tidy's "Handbook of Chemistry" (95).

Competition of the Processes—Theory of Eremacausis.—In addition to the four processes already mentioned, a patent for a fifth was taken out by Mr. Charles Payne in 1846 (64). His plan consisted in the injection into the timber, first of a solution of a sulphuret of barium or calcium, and next of a solution of sulphate of iron, the object being to form an insoluble sulphuret in the pores of the wood. This process was tried to some extent both in England and in France, but it was a complete failure, and is mentioned only by way of reference.

From 1838 to 1853, at which last date the Paper of Mr. H. P. Burt was read at this Institution, the four processes, Kyanizing, Margaryzing, Burnettizing and Creosoting had been in active competition. The prevailing theory at that time as to the causes of the decay of timber was shaped by the opinions of the great chemist Liebig. Liebig taught that the processes of fermentation in certain fluids, and of the putrefaction or decay of organized bodies, animal and vegetable, were caused by a species of slow combustion, to which he applied the term eremacausis. He held that this decomposition could be produced by contact with portions of other bodies already undergoing eremacausis. That it required for its ordinary development the presence of moisture and of atmospheric air; that its action was provoked by oxygen, and that its method of action was by a communication of motion from the atoms of the infecting ferment to the atoms of the body infected. He denied that fermentation, putrefaction and decomposition were caused by fungi, animalcules, parasites or infusoria, although these organisms might sometimes be present during the processes.

But he also stated that the phenomena of decomposition might be suspended by extreme heat or cold, that they were accelerated by the action of alkalies, and retarded by that of acids, and that they might be arrested by the use of certain antiseptics (47). If, however, the theory of eremacausis be accepted, and if its phenomena be due entirely to a communication of molecular motion, and not at all to the action of living germs, does any adequate explanation remain of the effects produced by antiseptics? With regard to timber, theorists were ready with an answer to this question, and

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they deduced their theories from further teachings of the great German chemist. Liebig, enlarging upon the views of previous investigators, had proclaimed the identity in composition of the animal and vegetable albumens. The blood of animals and the sap of plants are, during life, the circulating media of the vital growth; after death they are the portions of the respective bodies which putrefy most rapidly; both are largely composed of albumen (47). The sap freshly drawn from a tree will commence to putrefy within twenty-four hours. It was proclaimed (although probably not by Liebig), that the coagulation of the albumen was the true specific against the decay of wood. Corrosive sublimate, sulphate of copper, chloride of zinc, and the tar oils were all powerful agents for that purpose. It was claimed for all four of these processes that they coagulated the albumen contained in the wood, and that they formed insoluble compounds therein, thus arresting decay.

Prolonged experience has, however, proved that the salts of metals are not so permanent in their effects as the tar oils. The discussion which took place at this Institution in January 1853, upon the occasion of the reading of Mr. Burt's Paper, was an interesting one, and was joined in by most of the leading engineers of the country (6). Whilst the other processes were admitted, in many instances, to have done good service, the Creosoting process was generally held, after fifteen years' experience, to have proved the most stable and reliable. In many subsequent discussions, the prolonged duration of Creosoted timber had been a matter of constant and reiterated testimony. Gradually the Creosoting process took the place of the others, by a species of "survival of the fittest," until in England it entirely extinguished its rivals. The Author's last experience of Kyanizing in England was carried out in 1863.

In France, the Creosoting process was later in establishing itself, partly owing to the difficulty which at one time existed in procuring Creosote in that country, partly, also, to the popularity of the sulphate of copper process, enhanced, as it was, by the ingenuity of the method employed for its injection by Dr. Boucherie. But it was discovered even in France, and notwithstanding the theories of insoluble compounds being formed in the timber, that the salts of metals were gradually washed out of the wood in moist situations. In 1861, the French chemist Payen reported that sulphate of copper could be almost entirely removed from wood by repeated washings with water, and in 1867 he reported that the whole could be so removed (61). This has been confirmed by the testimony of Maxime Paulet (62).

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The experiments of Mr. Forestier, undertaken for the French Government, and the prolonged and exhaustive experiments of the Dutch Government, are conclusive as regards the efficiency of creosoting against the ravages of the *Teredo navalis*, in cases where the timber has been efficiently prepared, and with a suitable kind of Creosote. These experiments are referred to in the Minutes of Proceedings of this Institution, vol. xxvii. (13), (23), (40). The experiments undertaken by Mr. Crépin on behalf of the Belgian Government, and the independent testimony of many of the leading engineers of this country, have also from time to time been brought to the notice of this Institution, in confirmation of the success of the Creosoting process against the ravages of marine insects. On the other hand there are distinct and well-authenticated instances of failure. An inquiry into the causes of such failures is one of the main objects of this Paper.

Origin and Properties of the Tar Oils.—As the tar oils gained in usefulness, their varying qualities became subjects of increasing interest. A brief digression may here be useful, in order to show the process of manufacture by which these tar oils are procured. Referring to Plate 6, it will be seen that from coal, as it is carbonized at the gasworks, four well-known products are obtained, viz., illuminating gas, ammoniacal liquor, coal-tar, and coke. Gas liquor, or ammoniacal liquor, forms the basis of a separate industry; the ammoniacal products are of no utility for timber preserving. The antiseptic substances are all obtained from the distillation of coal-tar, a black, viscous substance, of a consistence resembling treacle. Plate 7, Fig. 1, shows the usual form of the wrought-iron tar-still, those at the Author's various works containing from 2,500 to 2,750 gallons at each charge. The tar is subjected to the heat of a furnace placed beneath the still, the operation being aided sometimes by the injection of steam, sometimes by the application of an exhausting air-pump. The products of distillation come over very nearly in the order of their respective volatilities, those of lightest specific gravity being followed in succession by heavier and yet heavier ones as the heat increases. The temperature during the distillation ranges from 180° to 758° Fahrenheit. This preliminary process, although now carried out with more skill and economy than formerly, has not varied much during the last fifty years in its main object, which is to break up the tar into three groups of products, viz., oils lighter than water (crude naphthas); oils heavier than water; pitch, the residuum of distillation, which last product is run out from the bottom of the still, and solidifies upon cooling into a hard black

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substance. It is in connection with the component parts of the two groups of oils, and their separate and subsequent treatment, that some of the best known and most brilliant discoveries of modern industrial chemistry have been developed (25), (27), (29). The oils lighter than water, however, have no part in the preservation of timber. It is not uncommon to hear inquiries as to whether the discovery of the aniline dyes has not, somehow or other, interfered with the quality of the Creosoting liquor. There exists a singular and unfounded prejudice on this subject. The materials for the aniline dyes are not, and never have been taken from the Creosoting liquor or heavy oils; they are taken exclusively from the oils lighter than water, which last have never been employed for the Creosoting process, and are valueless for timber-preserving. The benzols, toluols, &c., from which the aniline dyes are produced, are extremely volatile, like alcohol.

The heavy oils of tar, or dead oils heavier than water, constitute the "Creosote" of the timber yards. They contain numerous substances, some of them liquid, some semi-solid, varying considerably in their properties, but most of them are now recognised as antiseptics. Formerly, the whole mass of these heavy oils was used for timber-preserving as they were collected from the still, but each portion can, if required, be separated as it comes over, according to its volatility, or the solid matters can be separated by filtering, for subsequent treatment.

It has been seen that Mr. Bethell's original patent recommended the use of the mother liquor, or coal-tar, thinned with a portion of heavy coal-tar oil. So late as 1849, Bethell's licences for the use of his patent described the process as "saturating timber with the oils obtained by the distillation of gas-tar, either alone or mixed with gas-tar." The Author remembers how, in the early days of Creosoting, inspectors frequently refused to allow the thinner and lighter dead oils to be used without being thickened with tar. Tar, the mother liquor, necessarily included all the substances contained in the dead oils, plus the naphthas and the pitch. The reasons for not adopting the tar in its entirety are simply that the crude naphthas are useless as antiseptics, and would immediately evaporate, whilst the pitch, from its too great solidity, would form an impediment to the injection. The dead oils, therefore, came into use alone, and there crept into some of the specifications the contradictory prescriptions that the wood was to be Creosoted according to Bethell's patent, but that the Creosote was to be free from adulteration with coal-tar.

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The dead oils made in London, and in all places where the tar is produced from the carbonisation of the coal of the Newcastle district, are, as compared with other dead oils, the richest in semi-solid substances (naphthalene, anthracene, pyrene, &c.), and they require a higher temperature to volatilise. They are generally called "London oils." The dead oils of the Midland Districts are lighter, thinner, more volatile, and contain usually a larger proportion of the ordinary tar acids. They are usually called "Country oils." The Scotch oils are, many of them, still lighter, thinner, and more volatile, sometimes lighter than water. Some Scotch oils, however, have been proved to be of excellent quality.

As regards the question of thick or thin oils, there is no doubt as to the opinion and practice of the earlier introducers of the Creosoting process. In January 1853, Mr. Bethell stated that "the product of Newcastle coal contained a quantity of naphthalene, and that he was an advocate for its use" (4). In November 1864, he said that "the Creosoting process was not, as often described, a chemical process entirely;" that Creosote did coagulate albumen in the sap of the wood; "but that was not his only idea when he introduced the process; his object was to fill the pores of the wood with a bituminous, asphaltic substance, which rendered it waterproof, &c." (5).

The late Mr. H. P. Burt, whose labours in connection with the preservation of timber will be remembered by many of the older members of the engineering profession, was in the habit for many years of using, by preference, the heavier London oils, mixed at times with a small percentage of the country oils, the latter as solvents or diluents of the more solid material. The Author, whose connection with Mr. Burt commenced in 1850, remembers, amongst his first experiences of creosoting, the solid masses of naphthalene contained in the tanks before heating.

When the construction of railways commenced in India in 1850 and 1851, it was speedily discovered that the timber found in that country was subject to very rapid destruction by decay, and by the attacks of insects. A serious difficulty was encountered by engineers in procuring suitable sleepers, and the experiment was tried of forwarding Creosoted Baltic timber from this country. The first consignment of this material was sent out in December 1851, for the East Indian Railway Company. The results were promising from the first, and the exportation of Creosoted sleepers to India continually increased. The Minutes of Proceedings of this Institution contain numerous records of the rapid decay of

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unprepared timber in tropical climates, and also of the very great general success of Creosoted timber exposed to the same influences, chequered, however, with a few instances of partial failure, which should be as instructive as the successes. It may be interesting to refer to the two Papers by Mr. Bryce McMaster, upon Indian Permanent Way Materials, one read in 1859 and the second in 1863, in which the success of Creosoted timber in India is fully set forth (21). Mr. Juland Danvers, in his annual report to the Secretary of State for India for the year 1863, remarks that it is cheaper to send out Creosoted Baltic sleepers than to use those of indigenous wood. The printed report of the East Indian Railway Company for the year 1867 again records the success of creosoted sleepers, after sixteen years' experience of their use.

It becomes a matter of interest to ascertain the kind of Creosote which was used for these earlier Indian sleepers. When the exportation first began there was a Custom's duty upon the importation of Baltic timber into this country equal to about 20 per cent. on the value of the sleepers. The Author's firm made early arrangements for Creosoting in bond, and for this reason, and with trifling exceptions, all the sleepers sent abroad, although supplied by various contractors, were for many years Creosoted at the works of the Author's firm at Rotherhithe and at the Victoria docks. Their books contain accurate records of the origin of all the creosote used. As may be anticipated, by far the greater bulk was London oil; up to 1863 comparatively little Country oil, and in some years none at all, being used. In January 1853, Mr. Burt, in describing to this Institution the process which he used, spoke, as a matter of course, of Creosote becoming a hard compact mass at a temperature below 35° Fahrenheit (7). Ten years later, in February 1863, speaking with reference to the Creosoting of some sleepers, the success of which in India had just been announced, he described Creosote as becoming solid at a temperature below 40° Fahrenheit, and added that, in consequence, he had introduced a heating apparatus inside the Creosoting cylinder (8).

With the exception of a small experimental shipment of Larch and Scotch fir, all the sleepers sent to India have been of Baltic fir timber, from the Polish and Russian ports. The shipments were of the ordinary kind of wood, such as was in use at first for sleepers in this country, and were mostly of triangular section. Amongst them, for the first three or four years, were considerable quantities of white-wood, a wood somewhat liable to split in hot countries. Subsequently red-wood was stipulated for,

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and with good reason, in all Indian specifications. The quantity of Creosote injected into these sleepers was at first from 35 to 40 gallons to the load of 50 cubic feet, as compared with the 50 and 60 gallons of the present day. At present, not only is a larger quantity of Creosote injected, but more care is also expended in the selection of the wood than was formerly the case. If, therefore, the earlier sleepers shipped to India behaved well, it might be assumed that the quality of the Creosote at least was suited to the climate. Such Creosote, however, as was then used would now be rejected under the requirements of many of the specifications at present in force for the preparation of timber for tropical countries. It is a question for grave consideration whether the change has been for the better.

It is a matter of notoriety that for many years, an increasing demand has arisen for the thinner and lighter Creosotes. "Country oil" became more popular, and began to be mentioned in specifications. Inspectors preferred these thinner oils; they were injected with less trouble, and the timber looked cleaner, and less "muddy" after the process, especially in the winter, when the London oils are more solid. Contrary to the opinion of the introducers of Creosoting, the thin light "Country oil" came to be considered by many as the supreme type of excellence.

This view was adopted by the late Dr. Letheby, who was further influenced by the growing recognition of the wonderful antiseptic powers of carbolic acid. Discovered in coal-tar by Runge, a German chemist, in 1834, carbolic acid had gradually achieved the important position which it still holds as one of the most valuable of antiseptics for sanitary and surgical purposes. Carbolic acid in varying quantities was present in the tar oils; the other constituents of those oils were imperfectly understood; some of them now well known had not then been discovered. The success of the creosoting process was therefore by *à priori* reasoning attributed mainly, if not solely, by Dr. Letheby to the presence of the tar acids. In June 1860 Dr. Letheby published his views on this subject in the Journal of the Society of Arts (44). He considered carbolic acid to be the most effective constituent of the tar oils, and that the efficiency of the latter in preserving timber depended mainly upon the percentage of carbolic acid which they contained. He therefore concluded that the lighter portions of the dead oils were the best, viz., those portions distilling between 360° Fahrenheit and 490° Fahrenheit, as they contain the tar acids in greatest abundance. Naphthalene and para-naphthalene he desired to exclude as much as possible, as he held them to be of no

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value in the preparation of timber. He had found the proportion of carbolic acid in tar oils to range from 6 per cent. down to as low as 0·5 per cent. In a letter of his in the Author's possession, dated 5th June, 1863 (45), he alludes to two samples as containing "unusually large" proportions of tar acids; the quantities were respectively 6·4 per cent. and 10·1 per cent. In a lecture at Nottingham in 1867, Dr. Letheby described a specification which he had drawn up for an Indian railway. This specification dated 1865 is shown on Diagram, Plate 6 (46); it contains the following stipulations. The creosote is to have a specific gravity as near to 1,050 as possible, ranging from 1,045 to 1,055. It is not to deposit naphthalene or para-naphthalene at a temperature of 40° Fahrenheit. It is to contain 5 per cent. of crude carbolic and other coal-tar acids (by the caustic potash test). It is to yield 90 per cent. of liquid oil, when distilled from its boiling-point to a temperature of 600° Fahrenheit.

From an examination of upwards of seventy timber-preserving specifications in the Author's possession, ranging from 1849 to the present year, it is manifest that a new departure was thus inaugurated by Dr. Letheby. For the first time a boiling-point is fixed, a certain percentage of tar acids insisted upon, whilst the use of naphthalene and the heavier distillates is discouraged. This specification has long ceased to be used, but its stipulations have been copied, and in some cases carried to greater lengths, in more modern specifications, 10 per cent. of tar acids being occasionally required. Such specifications exclude the London oils if taken in their entirety as they come from the still. It is to be regretted that, at the period mentioned, there is no record of experiments having been made by any English chemists as to the actual effects produced upon timber by the various constituents of the tar oils taken separately. For want of such a test, it would appear that an important element in the question was for some years overlooked in this country.

So early as 1848 the French Académie des Sciences received a communication from De Gemini, detailing a series of experiments upon wood prepared with various antiseptics. This investigator endeavoured to prove that timber cannot be permanently preserved by the use of antiseptics which are themselves soluble in water, and for that reason he preferred the use of heavy oils, or bituminous substances. The Académie rejected the conclusions of De Gemini, more especially as he denied that solutions of sulphate of copper formed insoluble compounds with woody fibre (34).

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In 1862 Mr. Rottier presented a Paper to the Académie Royale de Belgique giving the results of a number of experiments as to the effects upon timber of the various constituents of coal-tar oil. He arrived at the conclusion that although carbolic acid (Acide Phénique) was a very energetic antiseptic, yet that owing to its volatility, the durable success of the Creosoting process was not due to its agency. He attributed that success to the heavier and less volatile portions which came over at the later periods of the distillation, and considered that the heavier they were the better (78).

Later on this investigation was taken up by Mr. Charles Coisne, who was then, and still is, an engineer in the service of the Belgian Government (17) (18) (19) (22). In 1863 Mr. Coisne commenced a series of experiments, the object being to determine, in a practical manner, which portions of the tar oils best preserved the timber. The results were so instructive, that in 1866 he inaugurated a new series of experiments, still more carefully conducted, which lasted until 1870. He procured samples of Creosote from England, Scotland, Belgium, and France. Four of these samples contained respectively 15 per cent., 15 per cent., 8 per cent., and 7 per cent. of tar acids by the usual test. The fifth was an oil of heavy specific gravity, specially prepared, and containing no tar acids. Yet this last sample produced better results than any of the others. Each sample was divided into portions. Wood shavings were saturated with these oils in the following different ways:—

1st. With the Creosotes as received.

2nd. With the Creosotes, supplemented by additional quantities of tar acids.

3rd. With the Creosotes, supplemented by some of the heavier portions of the same oils distilling over at a temperature exceeding 320° Centigrade (628° Fahrenheit).

4th. With the original Creosotes divided into the lightest, the medium, and the heaviest portions, with each of which the shavings were separately saturated.

A putrefying-pit (*pourrisoir*) was prepared, in which the shavings were placed on the 10th of November, 1866, together with other shavings not prepared. After four years' sojourn in the *pourrisoir*, they were removed and examined on the 16th November, 1870. The results were strikingly in favour of the heavier oils, and adverse to the tar acids, which last bodies appeared to have been wholly ineffective. The shavings which had been prepared with the lightest portions of the oils, although they had contained the

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largest portions of the tar acids, were, nevertheless, in the worst condition. Those prepared with the oils somewhat heavier were in most cases better preserved. Best of all were the shavings prepared with the heaviest oils, procured by distilling at the higher temperatures even when containing no tar acids; these last were all perfectly sound. The un-creosoted shavings were all rotten. Mr. Coisne believed that the best portions of the oils were the "green oils," distilling at high temperatures (17) (22).

These experiments are recorded at length in the "Annales des Travaux Publiques de Belgique," also in separate pamphlets (22). Their results have considerably influenced the practice of railway engineers on the Continent. The Belgian Government accepted the conclusions arrived at by Mr. Coisne, and for many years has based its creosoting specifications thereon, with highly satisfactory results. The specification for the Belgian State Railways does not stipulate for any tar acids; it requires that at least two-thirds of the Creosote must have been obtained by distillation at a temperature exceeding 250° Centigrade (482° Fahrenheit), and the remainder at a temperature exceeding 200° Centigrade (392° Fahrenheit). It allows 30 per cent. of naphthalene, which is calculated at the ordinary temperature. In a recent correspondence with the Author, Mr. Coisne, who has for more than twenty years superintended the Creosoting operations of the Belgian Government, confirms the results of those experiments by his subsequent experience.

So far the experiments and the experience of De Gemini, Rottier and Coisne appear to be in absolute contradiction with the theory that the Creosoting process owes its success to the tar acids. Yet the fact cannot be doubted, that the tar acids are powerful antiseptics, and that their presence arrests decay. What, then, is the explanation of this apparent anomaly?

The authorities on the tar acids are many and reliable. From amongst the learned and voluminous treatises which have been written respecting these bodies, fifteen references have been selected in Appendix 4 to this Paper (80 to 94) to authors in England, Scotland, France, Belgium, Germany, and America. None of them disagree as to the following facts: That carbolic acid is volatile at ordinary temperatures. That it is soluble in water. That its combinations are not stable. That it is a powerful germicide, but that its efficacy ceases so soon as it evaporates or is washed out of the substances intended to be preserved. Professor (now Sir Joseph) Lister, whose adoption of the antiseptic system for surgical purposes has revolutionized hospital-practice,

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speaks from his large and valuable experience as to the importance of carbolic acid in the treatment of wounds, but he also remarks that its volatility is sometimes an evil as well as a good (83). Dr. Sansom, whose recent work on antiseptics so ably epitomises the results arrived at by previous investigators, as well as those due to his own researches, speaks of it as the "aërial disinfectant" *par excellence* (90).

If this substance can be washed out by water, and if its volatility is one of its great merits, and occasionally a defect, for sanitary purposes, can it at the same time be considered as a durable agent amongst the oils injected into railway sleepers? Especially can this be the case in those tropical countries where extreme heat or torrential rains, or alternations of both, are prevalent? For piles and other timbers used for harbour-work, the comparative solubility in water of the antiseptic agents employed is also a matter of vital importance. What is true respecting carbolic acid will also apply, to a great extent, to cresylic acid, the last substance being, however, somewhat less volatile and less soluble than the former. Do these bodies become stable by entering into combination with woody fibre? Their instability in this connection is apparently pointed out by Mr. Coisne's experiments. It may, however, be objected that these experiments were not conducted under the conditions to which railway timbers are exposed. This point also has been very fully investigated.

In 1867 Mr. Coisne obtained some Creosoted sleepers which had successfully resisted decay during periods of from eighteen to twenty years. The wood was crushed, and the substances obtained therefrom tested. He found no tar acids; if they had ever been there, they were no longer present. He found, however, a quantity of naphthalene; also of an oil which did not commence to distil until 230° Centigrade (446° Fahrenheit) (18) (22).

In 1882 the Author caused some similar experiments to be made. Through the kindness of the authorities of the London and North-Western Railway Company, eleven pieces of old Creosoted sleepers were sent from their permanent way. They had been in use for the following periods:—

1	specimen	16 years.
1	"	17 "
2	"	20 "
2	"	22 "
1	"	28 "
2	"	29 "
1	"	30 "
1	"	32 "

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Sleepers were also received from the Taff Vale Railway, the South-Eastern Railway, and the Great Eastern Railway, which had been in use for periods varying from fourteen to twenty-three years. A portion was also taken from a Creosoted pale fence, which had been fixed in the Victoria docks in 1855, and which is still in place, perfectly sound and strong, after twenty-nine years' use. A careful analysis of these seventeen specimens, all of ordinary Baltic fir, gave the following results.

1st. In no cases were any tar acids detected by the ordinary tests.

2nd. In fourteen out of the seventeen specimens the semi-solid constituents of the tar oils were present; in twelve of them was naphthalene, this body being in some cases in considerable quantity.

3rd. Only small percentages remained of oils distilling below 450° Fahrenheit. In the majority of instances from 60 per cent. to 75 per cent. of the total bulk of substances retained in the wood did not distil until after a temperature of 600° Fahrenheit was reached.

It is clear, therefore, that these timbers had been preserved by the action of the heaviest and most solid portions of the tar oils, and that the other constituents had disappeared.

4th. In some of these specimens acridine was searched for and detected. This substance is one of the alkaloids or bases now known to exist in the Creosote oils. This is probably the first occasion upon which acridine has been publicly mentioned in connection with the injection of wood; but the Author is persuaded that it will come to be recognised as one of the most valuable constituents of the tar oils for timber-preserving purposes. It was discovered by Graebe and Caro (1) (2); it is a powerful germicide, and solidifies within the pores of the timber, from which it neither evaporates nor washes out. It is intensely acrid and pungent (1) (2).

Portions of the same specimens of wood, fifteen in number, were sent to Mr. Greville Williams, whose original researches with relation to coal derivatives have been for so many years known to the scientific world. Mr. Greville Williams tested the samples of woods for tar acids, naphthalene, and the alkaloids. For the tar acids he found all ordinary tests fail, until he employed the extremely delicate one by bromine and ammonia. In some cases, even by this test, no phenols could be detected, but in most cases he succeeded in detecting faint traces of those bodies; generally less than one part in three thousand; minute portions, probably of the heaviest particles of the tar acids which had been

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incorporated and retained by the heavier portions of the oils. It is needless to say that these infinitesimal quantities could be of no practical value in preserving the wood. In all the specimens, save two, he found naphthalene. The presence of the antiseptic alkaloids was distinctly proved, and one of these bodies, called cryptidine, which he had discovered in Creosote oils in 1856 (31) (99), was detected by him in one of the specimens. Mr. Greville Williams concludes that the preservative action of the Creosote oils is due more to the bases or alkaloids than to the tar acids, as the former remain after the latter have disappeared. These researches were published in the "Journal of Gas Lighting," and also in a pamphlet in the possession of this Institution (28) (102).

Reference is now requested to Plate 6, and Appendix 1. In Plate 6, as already noticed, the constituents of the Creosote oils are arranged in the order of their respective volatilities. First, and most volatile of all, are the carbolic and cresylic acids, which are also freely soluble in water at ordinary temperatures; they come over from the still, incorporated with the lightest portions of the oils. Pure carbolic acid would entirely disappear by evaporation, if not secured in a stoppered bottle (80 to 94). Next in order comes naphthalene, which is much less volatile than the tar acids. It is not soluble in cold water, and almost insoluble in boiling water (53) (100). As it comes from the still it is of a yellowish colour, and, mixed with the heavy oils, it gradually becomes black on exposure to the atmosphere. It forms the principal constituent of the thick muddy-looking substance which sometimes forms on the surface of Creosoted timber, and which may often be seen adhering to the ends of railway sleepers for several years after they have been placed in the line. When sublimed by the action of heat and a current of air, it forms the beautiful frost-like substance well known in Creosoting yards. It becomes quite solid at a low temperature, and in that condition would be an impediment to the injection of the timber — a difficulty removed by heating the oils to about 100° Fahrenheit, at which temperature naphthalene becomes liquid. After injection it solidifies, and greatly assists in filling up the pores of the wood.

The following simple experiments, which have been tried and repeated in many different ways at the Author's laboratories during the last few years, are in strict accordance with the now well-known characteristics of naphthalene and the tar acids.

1. If tar-acids and naphthalene be separately exposed either at the ordinary temperature, or at the tropical heat of 130° Fahren-

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heit, the tar acids will evaporate much more rapidly than naphthalene.

2. Injected into timber the same results follow.

3. Light thin oils, containing large percentages of tar acids, evaporate more quickly than heavier oils containing less tar acids and more naphthalene, when tested by methods Nos. 1 and 2.

In weighing after these experiments great care must be taken to allow for the absorption of moisture from the atmosphere. The tar acids absorb moisture before finally evaporating. Wood also absorbs a large amount of moisture when injected with oils containing these acids.

4. By repeated washings with cold water, all the carbolic acid, and all or nearly all the cresylic acid, can be washed out, both from Country and from London oils. (Appendix 5). These experiments assume especial importance in considering the durable effects of various kinds of Creosote for protecting timber immersed in sea-water from the attacks of marine insects.

Dr. Meymott Tidy has published the results of his experiments upon naphthalene (54), (97), (30). He injected pieces of wood with this substance, and exposed them to a temperature of 150° Fahrenheit. He found that the evaporation was only superficial, and that it practically ceased after forty-eight hours, the naphthalene below the surface remaining within the pores of the wood. Naphthalene is now recognized as an antiseptic, not so powerful in its immediate effects as the tar acids, but more durable. It is probable that tar acids of a heavier and less volatile type than carbolic or cresylic acids, may be more reliable as antiseptics for preserving timber.

Following in the series of distillates, amongst the Creosote oils are the alkaloids or bases of the quinoline or leucoline group, amongst which chemists are searching, not without fair promise of success, for a febrifuge similar to, if not identical with, the quinine derived from the cinchona plant. In this group occurs the substance called cryptidine (28) (99), already alluded to as one of the valuable antiseptics discovered in those portions of the oils which were formerly characterized as "inert."

Para-naphthalene, mentioned in Dr. Letheby's specification, has since then become the basis of one of the most interesting chemical discoveries of the age. It was excluded by Dr. Letheby from the oils intended for timber-preserving, and is probably without value for that purpose. It is now called anthracene, and is extremely valuable as the substance from which alizarine is manufactured, thanks to the brilliant discoveries of Perkin in England, and of

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Graebe, Liebermann and Caro in Germany. Alizarine is the colouring matter used by Turkey-red dyers and printers; for ages it had been extracted from the madder root. It is now made from the coal-tar product anthracene, of a far higher degree of purity, and at an enormously decreased cost. The madder root has gone almost entirely out of cultivation (25). The quantity of anthracene contained in tar is relatively small.

Amongst the green oils, distilling between 550° Fahrenheit and 750° Fahrenheit, is found the acridine already alluded to as a valuable germicide and stable antiseptic (1), (2). Phenanthrene, carbazol, pyrene, chrysene, and benzerythrene, by no means complete the list, which is constantly being added to by new discoveries of the numerous bodies in which these dead oils are so prolific. The properties of many of these heavier bodies are still imperfectly understood; but from the fact that they will not evaporate except at exceedingly high temperatures, they are valuable ingredients for timber-preserving.

By the light of the evidence now accumulated, it may be advisable to review the question as to the relative value of these various bodies contained in the heavy oils as regards the preservation of timber. Some of them are becoming valuable for other purposes. Which of them should the engineer retain for injecting wood?

Can the conclusion be resisted, that for this purpose the efficacy of the tar acids has been over-rated, and this at the expense of the more stable and enduring portions of the tar oils? The London oils as they come from the still are not sufficiently volatile to meet the exigencies of some modern specifications, nor do they comply with these exigencies as regards the percentage of tar acids. They do not, as a rule, contain more than from 4 to 7 per cent. of tar acids, and they will not yield 90 per cent. of their bulk by distillation below 600° Fahrenheit. Therefore a pressure is put upon the manufacturer to meet the fashion by "taking out" some of the heavier portions, and in some instances this is done. By this means the bulk is rendered lighter, and the proportion of tar acids to the diminished bulk is increased. For these heavier portions, especially for the green oils, a market is found for lubricating and other purposes. But in the Author's judgment the efficacy of the oils as antiseptics for wood is thereby diminished. The green oils, after the anthracene has been removed from them by filtration, should be returned to the Creosote tank. The percentage of tar acids to be used remains a contested matter of opinion. But the Author ventures to express the hope that at

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least the lighter portions of the tar acids, and especially carbolic acid, may soon be relegated altogether to their important functions as sanitary antiseptics, for which they are so valuable, instead of being wasted by the attempt to use them as antiseptics for timber, for which their peculiar properties render them unreliable. Upon the whole it would be wiser to revert, to a larger extent and with increased knowledge, to the plan of using the London oils mixed with the Country oils, and encouraging instead of discouraging the use of the heavier portions. The whole of the Creosote oils manufactured from ordinary Gas Tar in this country are required for preserving timber, and to exclude one considerable portion of the supply is to enhance unnecessarily the cost of the rest. No oils, however, should be used as Creosotes which are lighter than water. Both bone oil and shale oil are sometimes offered as Creosote oils. (Appendix 2.)

In 1881 Professor (now Sir Frederick) Abel and Dr. Tidy drew up a joint Creosoting specification (96), in which as the result of direct experiment they resolved to exclude no semi-solid bodies which completely melt at 100° Fahrenheit. They further changed the standard of volatility from 90 per cent. at 600° Fahrenheit to 75 per cent. Subsequent and prolonged investigation induced Dr. Tidy to go still further in the same direction, and not only to withdraw the clause limiting to 25 per cent. the oils distilling at a higher point than 600° Fahrenheit, but even to require that at least 25 per cent. of those non-volatile oils must be present. The Author's experience leads him entirely to agree with the progress made in this direction.

Conflicting Theories on Putrefaction—the Germ Theory.

If experiment and experience should lead to clearer views as to the relative value of various antiseptics, it may be advisable to test those views by reference to the recent development of theory upon the causes of decomposition in organized bodies. How do antiseptics act upon timber? Is the coagulation of albumen a sufficient explanation of their preservative action? Surely not. Many substances, boiling water included, which will effectually coagulate albumen, will not prevent the decay of wood. Coagulation retards, but does not prevent the decay of albumen itself Again, the quantity of albumen in fir timber is exceedingly small, if the tree be cut down, as it generally is and always should be, during the season when the sap is not circulating. From a number of experiments made upon ordinary fir sleepers, the Author arrives

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at the conclusion, that the quantity of nitrogenous matter or albumen which they contain does not usually much exceed 1 per cent. of their weight. Any watery fluid containing from 2 to 3 per cent. of tar acids would effectually coagulate this quantity of albumen. In some cases it is found that a portion of this albumen is actually coagulated by substances naturally contained in the timber. But the coagulation does not of itself preserve the wood (22), (84), (63). Liebig's theory of decomposition has already been alluded to. He maintained that putrefaction was due to eremacausis or slow combustion, produced by contagion, the infected bodies communicating a molecular motion to the atoms of the bodies with which they come in contact, and that these phenomena are not caused by the action of germs or living organisms (47).

The modern germ-theory distinctly traverses this last assertion (98). Pasteur affirms, that without the presence of living germs, the phenomena of organic decomposition do not accomplish themselves, and that these germs are the veritable agents of the decomposition (56). The laborious experiments, and the lucid deductions of Professor Tyndall, confirm the experiments and theories of Pasteur (98). Professor Tyndall explains that the air is laden with clouds of germs, agents of decomposition ever ready to settle down and develop upon matter suitable to their growth. He finds that the contents of tubes filled with the most putrescible materials, animal or vegetable, can be preserved from putrefaction indefinitely, by the exclusion of germs. But that it is not sufficient merely to poison or neutralize one generation of organisms, the incursions of fresh myriads must be excluded, or putrefaction will ensue.

After reading the "Essays on the Floating Matter of the Air" (98), in which Professor Tyndall describes how the germs gradually fell into the open tops of the test-tubes, let the comparison be made between the mouths of these tubes and the gaping orifice of a crack produced by the sun in a piece of timber. Through it the germs will descend, and if there is nothing to arrest their action, and if the crack is deeper than the portion of the wood charged with antiseptics, they will carry destruction into the centre of the log. But if the antiseptic be of an oily or bituminous nature, it will flow into the cracks when they first develop themselves, and seal up the orifices against the enemy. Examine a crack or a wound in the trunk of a living fir-tree; it will be found that by a natural process, a resinous substance exudes, which closes the wound against the agents of destruction.

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The bodies of mammoths preserved in ice through countless ages, the trees of primeval forests excluded from the air beneath thick deposits of peat, the fragments of wooden piles which have endured undecayed for centuries when driven deeply below the surface of water, all confirm the experiments of Pasteur and Tyndall, and prove that the exclusion of germs prevents putrefaction. Specimens are exhibited of a wooden pile from the remains of the bridge (destroyed by fire) which was constructed by Charlemagne across the Rhine at Mayence; of pieces of piles from the foundations of the bridge across the Medway at Rochester, which was destroyed by Simon de Montfort in 1264, and which was probably then about one hundred years old; also from the new bridge erected to replace the former one in 1283.

It is not for the Author to draw the dividing line between the decomposing action of germs and the action of oxidation. It is sufficient for his purpose to submit that all influences which either destroy or exclude germs, will prevent decay so long as those influences endure; but that permanent effects must not be relied upon from agents which are not themselves permanent and abiding. The germ-theory then becomes a severe but a salutary test in choosing antiseptics for the treatment of timber. Such treatment is of little value unless its effects will endure for long periods. Reliance, therefore, must not be placed upon those germicides, however potent, which will readily volatilize in air, or dissolve in water. A growing scepticism arises from experience as to insoluble compounds being formed between woody fibre and substances which are themselves soluble in water. In short, the substances to be employed should by preference be antiseptics in a double sense; they should be both germicides and germ excluders. From the long list of germicides must be especially excluded such as injure or weaken the fibre of the wood; amongst these latter must be classed all solutions with very strong acid or alkaline reactions; also some of the metallic salts. It has been seen, that the salts of zinc, mercury, and copper have been to some extent successful; of these the Author's experience induces him to prefer sulphate of copper, as less soluble in water than chloride of zinc, and not volatile like corrosive sublimate. Even sulphate of copper cannot be permanently relied upon, when exposed to the continuous action of water; but it may be found useful in comparatively dry situations, or as a protection against dry-rot to timber under cover. From its properties as a germicide, sulphate of copper might be usefully

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employed in conjunction with oily or bituminous fluids, even with oils which do not possess great potency as germicides (12).

From all research and experience it would, however, appear, that the same conclusions may be derived, viz., that the best antiseptics for timber are to be found amongst oils and bitumens which fill up the pores of the wood. Of such bodies, those which contain germicides are to be preferred. And, other properties being equal, those which either solidify in the pores of the wood or which require an extremely high temperature to volatilize them, and which are insoluble in water, must surely be the best of all.

Apparatus for Timber-Preserving.—Of the apparatus employed for applying antiseptics to wood, the most ancient and the most popular is the tar-brush or the paint-brush. During the last century, and in the earlier portion of the present, steeping in tanks was extensively adopted, the various liquids being employed either cold or heated. A marked improvement was introduced in 1831 by Mr. Bréant, a director of the Mint of Paris, who invented the first apparatus for injecting timber by means of vacuum and pressure, in a closed iron cylinder; he employed by preference linseed-oil and resin. The cylinder was fixed vertically, an inconvenient arrangement not necessary to the efficiency of his process. The iron cylinder and the process by vacuum and pressure were adopted by Mr. Bethell, and greatly improved by him and by Mr. H. P. Burt, who were associated together for some years. The cylinder was enlarged, its fittings strengthened and simplified, and an interior heating apparatus added. In Mr. Burt's Paper of January, 1853, there is a full description of this machinery; its main features are still the same in the usual Creosoting apparatus of the present day (6) (20). These cylinders, being of wrought-iron, were applicable to Creosote oils, and to chloride of zinc; but not to salts having a corrosive action upon iron, such as sulphate of copper and corrosive sublimate. In 1842, Mr. Timperley described to this Institution a method which he had adopted on the Hull and Selby Railway, for lining the iron cylinder in order to preserve it from the action of corrosive sublimate. This method and the expedient of smearing the inner surface with pitch, were proposed and tried for sulphate of copper injections with but partial success. The Author had several cylinders materially injured or destroyed by the corrosive action of these salts. In 1857 Messrs. Legé and Fleury Péronnet, introduced an apparatus of which the cylinder, trucks and pressure-pumps were entirely of copper; and machinery of this costly description is

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still used for the Southern Railways of France, at Labouheyre. In 1865 the Author took out a patent for the following apparatus (10):—Inside the iron cylinder he placed a wooden tank, which contained the timber to be operated upon, and in which was the sulphate of copper solution. It was an open wooden tank, inside a closed iron cylinder. The pressure applied was that of condensed air, a condensing air-pump being used, capable of maintaining an effective pressure of 200 lbs. to the square inch. By this means, the timber was injected with the copper solution without injury to the iron cylinder.

The process of Dr. Boucherie (15) was at one time largely used in France. It consisted in the injection of newly-fallen timber in the forest by the vertical pressure of a column of the antiseptic solution, generally sulphate of copper, which was conducted through a pipe from a small reservoir fixed at a height of 30 or 40 feet. The tube was attached by an ingenious arrangement to the end or middle of the log; the antiseptic liquid expelled the sap from the softer parts of the timber, and took its place. The process is still used to a small extent in France, principally for telegraph poles.

Various attempts have been made to imbue timber with the vapours of oils, either by employing the tensions of the vapours themselves, or by the use of the pressure-pump. The first experiment of this kind appears to have been made by Lukin, in the Dockyard at Woolwich in 1812, when the apparatus exploded, with fatal consequences to the workmen employed, and the attempt was abandoned (39). The patents of Franz Moll in 1836 (49), of Bethell in 1864, and other subsequent patents, claim the invention of the principle of injecting Creosote oils in a state of vapour. If this could be conveniently or safely carried out, the system might possess some advantages. But there is a fatal objection to its employment. Timber is weakened by exposure to a temperature much exceeding 250° Fahrenheit, whilst at 300° Fahrenheit, or a little above, it commences to decompose, and becomes seriously injured. Now the boiling-point of the Creosote oils ranges from a little below 400° Fahrenheit up to about 760° Fahrenheit. As with the steam of water, so is it with the vapour of oils—no pressure can be obtained with them, except at a temperature exceeding their boiling-point. The vapours of the Creosote oils cannot, therefore, be injected into timber except at temperatures, and under conditions of pressure, which would destroy the value of the timber as an engineering material. The process has been tried in France, and it failed, owing to the complete deterioration of the timber.

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A modification of this system has, however, been carried into practice. Super-heated steam was passed through Creosote oils, and then injected into the sleepers (which had been previously warmed by steam), with the idea that the mingled vapours of water and Creosote might be injected into the timber at a temperature of from 290° Fahrenheit to 320° Fahrenheit. With this modified process, the Author's firm carried out some extensive operations for the Western Railways of France, it being the desire of the engineers of that Company to economize the Creosote, and to try whether in a finely divided state, a smaller quantity might not suffice by being more deeply injected. The operation was supplemented, however, by an injection of Creosote in the usual fluid state.

After prolonged trials, the first part of the operation was discontinued by order of Mr. Bouissou, the Company's engineer of the permanent way. It was found, whenever the cylinder was opened before the second operation, that a small portion of the lightest particles of the Creosote had been carried over mechanically into the cylinder by the super-heated steam. Once within the cylinder, however, the two fluids obeyed the laws which govern their respective volatilities: the Creosote oil sank to the bottom of the cylinder, and the vapour of water only was injected into the timber. The sleepers on examination and testing by the ordinary tests, contained neither tar oils nor tar acids.

An analogous experiment tried at the Timber Preserving Works of the Austrian North-West Railway, is described in the journal of the Bohemian Architects, and Engineers' Institute for 1880, by Mr. J. Seidl (79), and the process has been condemned for very similar reasons.

Condition of Timber at time of Preparation.—Getting rid of Moisture by stacking or artificially.—The hygrometric condition of timber at the time of injection is an important element in the success of the operation, all important with the Creosoting process especially. Neglect on this point has often been the cause of partial or total failure. Woody fibre in itself is heavier than water, its specific gravity being generally considered as equal to 1·5, water being 1·0 (63). It is, therefore, owing to the looseness of their texture, that so many kinds of timber are lighter than water. The specific gravity of fir timber varies ordinarily between 0·5 and 0·8; the difference arising as often from the varying density of the timber itself, as from the quantity of water contained. As fir timber can, under certain conditions, absorb so much moisture as to become water-logged, or actually heavier than water, its powers of absorption can be calculated

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from its specific gravity. It can take up as much as from 60 to 150 gallons of water to the load of 50 cubic feet, the maximum quantity being, of course, an exceptional possibility. Fir and pine, however, frequently contain as much as from 15 per cent. to 20 per cent. of water, after from two to three years' stacking (63). The question of the pernicious effects of an excess of moisture in the timber at the time of Creosoting, has been from time to time brought before this Institution by Mr. Bethell, by Mr. Burt, and by the Author (13), (25). Large logs taken out of timber ponds, or sleepers freshly imported, are not in most cases in a fit condition for Creosoting until after having been stacked for from four to six months. The Author, in common with most of the earlier operators in this process, has tried various methods for artificially drying the timber. Steam, ordinary and super-heated, currents of hot air, and drying stoves or ovens, have been used for this purpose, but have all, in this country, been abandoned. To subject timber to a dry heat, elevated enough to remove its moisture with the necessary rapidity, will invariably result in injury to the wood. Timber piles stoved before Creosoting, prove brittle when driven. The action of the air-pump in the ordinary process assists the operation by withdrawing air from the pores of the wood; but it is a mistake to suppose that it has much effect in withdrawing moisture.

These difficulties have perplexed the Author for many years. He has recently devised a method by which to get rid of the moisture as part of the timber-preserving process, and without injury to the wood (11) (14) (26). An experiment easy to reproduce, and which explains the nature of this operation, is depicted in Plate 7. Fig. 2 represents an ordinary glass flask, in which are placed some pieces of wood saturated with water—the neck of the flask is connected by glass tubes with an experimental air-pump. By working the pump the air is extracted from the pores of the timber, but however efficient the vacuum may be, no perceptible moisture is withdrawn, nor would the water be removed from the wood except by a slow evaporation prolonged beyond practical limits. This represents the ordinary action of the air-pump upon timber in a Creosoting-cylinder. If sufficient heat be now applied beneath the flask, the water will become volatilized, and will be withdrawn rapidly in the shape of steam by the action of the air-pump. But the wood will be found to crack, and open to an extent which is not desirable. This illustrates the result of applying dry heat.

Fig. 3 represents a similar flask with a condensing apparatus

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added; moreover the flask now contains Creosote oil, in which the wet timber is submerged. It must be constantly borne in mind that at the ordinary tension of the atmosphere, the boiling point of the creosote oils ranges from about 380° Fahrenheit to 760° Fahrenheit, as compared to water at 212° Fahrenheit. These boiling-points are, however, lowered, according to a well-known law, by the effects of a vacuum. Let the Creosote in the flask be now heated to 212° Fahrenheit, whilst the air-pump is put into operation. The heat being communicated through an oily medium will not injure the timber, from which the water is volatilized, and drawn out by the air-pump. The Creosote oils are not volatilized, as the temperature is far below their point of ebullition. The water is speedily and effectually removed, and the Creosote takes its place.

Plate 7, Fig. 4, represents the ordinary Creosoting apparatus, supplemented by the additional fittings required to carry out the process just described. By the ordinary and well-known process, after the timber has been placed in the cylinder and the air-tight door closed, the air is exhausted from the cylinder, the Creosote is then introduced heated to a temperature of from 100° Fahrenheit to 120° Fahrenheit, when the air-pump ceases to work, and the pressure-pump is put into operation.

Referring now to the new process, it will be seen that a large dome is placed on the top of the cylinder, to which the exhaust-pipe of the air-pump is attached. The exhausting process is continued after the Creosote has been introduced into the cylinder. The Creosote during this part of the operation should not be allowed to rise quite to the top of the vessel, a free space being preserved, and the dome kept empty, so that the Creosote is not drawn through the exhaust-pipe. The Creosote is raised to a temperature a little exceeding 212° Fahrenheit instead of 120° Fahrenheit as heretofore. The exhausting process is continued until all the water is extracted from the timber in the form of vapour, drawn through the dome, condensed by passing through the worm of the condensing apparatus, and collected in the receiving tank, where the quantity extracted can be measured. With charges of very wet sleepers, the Author has succeeded in withdrawing water equal in volume to 50 gallons per load of timber, and replacing this water with an equal volume of Creosote by the action of the air-pump alone. If necessary, however, the pressure-pump can be afterwards applied in the usual way.

A slight additional cost, and a few hours' additional time are necessary for dealing with very wet timber by this process as com-

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pared with the ordinary method. But the expenditure in time and money is not so great as would be required by stoving the wood before Creosoting. If, in the absence of artificial methods, timber be stacked for six months, as it should be, the interest on capital represents a certain expenditure also. The Author ventures to suggest that this is not always taken sufficiently into account, in giving out contracts for creosoted timber. Other conditions being equal, dry timber is at a disadvantage in the competition, as far as price is concerned, with timber just landed. Yet a small extra expenditure in this particular would frequently be repaid to the consumer twenty or thirty-fold in the prolonged duration of the wood.

Conclusion.—In conclusion the Author would remark that with regard to certain points mentioned in this Paper, upon which some controversy has at times arisen, he has been careful to advance no opinion which he has not confirmed, either by the opinions and investigations of eminent authorities, or by careful and reiterated experiments. Many hundreds of experiments have been in fact carried out at the laboratories of the Author's firm at Silvertown during the last five years, with the especial object of investigating the properties of the tar oils and other antiseptics, and their behaviour in contact with timber. To Mr. Royle, Mr. Bendix, and Mr. Holmes of the chemical staff of his Silvertown Works he has to return his best thanks for their skilled assistance, and particularly to Mr. Bendix, who has been more especially entrusted with the conduct of these experiments. To Mr. Gabbett he is indebted for the drawings exhibited.

The treatment of Timber by Antiseptic methods has been acknowledged by some of the greatest engineers of this country to have been useful to the art of constructive engineering. It may be made even more useful in the future than it has been in the past. All that the advocates for its still more extended development can desire to claim will be, that their methods and investigations may be seriously examined, and from time to time decided upon, in accordance with the results which science and experience may bring to light.

The Paper is accompanied by several drawings, from which Plates 6 and 7 have been prepared.

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APPENDICES.

APPENDIX 1.—DISTINCTIVE PROPERTIES of VARIOUS COAL-TAR PRODUCTS.

Name.	Formula.	Sp. Gr.	Boiling Point, Fahrenheit.	Melting Point, Fahrenheit.
			°	°
Benzol	C_6H_6	0·880	176·7	..
Toluol	C_7H_8	0·872	230·5	..
Xylol	C_8H_{10}	0·865	282·2	..
Cumol	C_9H_{12}	0·870	330·8	..
Pyridine	C_5H_5N	0·980	242·0	..
Carbolic acid (phenol or acide-phénique)[1]	C_6H_6O	1·065	359·6	107·6
Cresylic acid or cresol	C_7H_8O	1·050	388–397	..
Naphthalene	$C_{10}H_8$	1·153	424·4	174·2
Leucoline or quinoline	C_9H_7N	1·081	460·4	..
Cryptidine	$C_{11}H_{11}N$	..	496·4	..
Phenanthrene	$C_{14}H_{10}$	..	644·0	204–212
Carbazol	$C_{12}H_9N$	..	671·0	460·4
Anthracene or para-naphthalene	$C_{14}H_{10}$	..	680·0	415·4
Acridine	$C_{13}H_9N$	..	680·0	224·6
Pyrene	$C_{16}H_{10}$	..	700·0	287·6
Chrysene	$C_{18}H_{12}$	..	824·0	482·0
Benzerythrene	$C_{24}H_{18}$	..	..	584–586

[1] In French specifications the term acide phénique is usually applied to all tar acids which are removable by the caustic alkali tests.

APPENDIX 2.—PROPERTIES of SUBSTANCES not DERIVED from COAL-TAR.

Name.	Sp. Gr. at 60° Fahr.	Sp. Gr. at 100° Fahr.	Boiling or Decomposing Point, Fahrenheit.	Melting Point, Fahrenheit.
			°	°
Bone oil	0·946	..	350	..
Olive oil	0·915	..	600	..
Palm oil	..	0·890	above 600	80–95
Cotton-seed oil	0·922	..	600	..
Linseed oil	0·930	..	above 600	..
Resin oil	0·990	..	600	..
Paraffin oil	0·805	..	340	..
Shale oil	0·870	..	550	..
Creosote (true creosote the product of the destructive distillation of wood)	1·076	..	410–425	..

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APPENDIX 3.—TIMBER PRESERVING SPECIFICATIONS.

Year.	Name.	Substance employed.	Specification.
1832 1836	J. H. Kyan, Patent No. 6253 „ „ 7001	Deuto-chloride of mercury, or corrosive sublimate .	1 lb. of salt to 5 gallons of water, used hot or cold. Immersion for from seven to twenty-one days.
1837	J. J. L. Margary, Patent No. 7511 .	Sulphate or acetate of copper . . .	1 lb. of salt to 4 gallons of water. Immersion two days per inch of thickness of wood.
1838	Sir W. Burnett, Patent No. 7747 . .	Chloride of zinc .	1 lb. of salt to 5 gallons. Immersion for from ten to twenty-one days.
1838	J. Bethell, Patent No. 7731 . .	Saline solutions and resinous or bituminous substances. Coal tar thinned with one-third to one-half its own quantity of dead oil. Caoutchouc or resin may be added.	
1865	Dr. Letheby .	Creosote oil . . .	Sp. gr. at 60° F. 1045–1055, as near 1050 as possible. Not to deposit naphthalene or para-naphthalene at 40° F. To yield not less than 5 per cent. tar acids, and not less than 90 per cent. of liquid oil at 600° F.
1869-1884	Belgian Government	Coal-tar creosote .	Not to contain more than 30 per cent. naphthalene at ordinary temperature. Two-thirds must distil above 482° F. None to distil under 392° F.
1883	Dr. Tidy . .	„ „ .	To be completely liquid at a temperature of 100° F. Must contain at least 25 per cent. of constituents that do not distil at a temperature of 600° F. To yield a total of 8 per cent. of tar acids.
1884	Sir Frederick Abel . .	Creosoting liquor or heavy oil of tar .	Completely fluid at 100° F. To contain not less than 20, nor more than 30 per cent. of constituents that do not distil at a temperature of 600° F. To yield not less than 9 per cent. of tar acids. Spec. gravity 1,035 to 1,065.
1864 to 1884	Western Railways of France	Creosote	To contain 5 per cent. of tar acids (acide phénique).

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APPENDIX 5.

Experiment with two specimens of tar-oils containing respectively 10 per cent. and 17·5 per cent. of tar-acids by the ordinary caustic soda test. The object was to ascertain what proportion of the tar-acids could be removed by repeated washing with cold water.

Specimen of mixed London and Country Oil.

Test before Experiment.

	Per Cent.
Total distillate at 600° Fahr.	70
Tar-acids	10
Water	2
Sp. gr. at 60° Fahrenheit	1,068

20 ozs. of oil washed with cold water seventeen times (1,020 ozs. of water used).

Test after Experiment.

Total distillate at 600° Fahr.	70·0
Tar-acids	3·5
Water	1·0
Sp. gr. at 60° Fahrenheit	1,071

Again washed with cold water fifteen times (900 ozs. of water used).

Test after Experiment.

Total distillate at 600° Fahr.	69·0
Tar-acids	1·5
Water	Free
Sp. gr. at 60° Fahrenheit	1,073

Specimen of Country Oil.

Test before Experiment.

	Per Cent.
Total distillate at 600° Fahr.	85·0
Tar-acids	17·5
Water	3·0
Sp. gr. at 60° Fahrenheit	1,046

20 ozs. of oil washed with cold water seventeen times (1,020 ozs. of water used).

Test after Experiment.

Total distillate at 600° Fahr.	83
Tar-acids	6
Water	3
Sp. gr. at 60° Fahrenheit	1,049

Again washed with cold water fifteen times (900 ozs. of water used).

Test after Experiment.

Total distillate at 600° Fahr.	79·0
Tar-acids	3·5
Water	Free
Sp. gr. at 60° Fahrenheit	1,053

It will be seen that by merely washing in cold water the original bulk of tar-acids was reduced in the one case from 10 per cent. to 1·5 per cent., in the other case from 17·5 per cent. to 3·5 per cent. The small proportion of tar-acid remaining, in both cases, contained no carbolic acid by the bromine and ammonia test; it did not boil until 420° Fahrenheit, which may be considered as too high a temperature even for cresylic acid. It is probably one of the higher phenols.

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APPENDIX 6.

SPECIMENS EXHIBITED DURING THE DISCUSSION UPON MR. S. B. BOULTON'S PAPER ON "THE ANTISEPTIC TREATMENT OF TIMBER."

A piece of Oak timber (sound) from the ruins of the Carolus Bridge, Mainz; erected by Charlemagne, and destroyed by fire.

Portion of an Oak pile (sound) which formed part of the first bridge on the Medway at Rochester, driven in about the year 1180. This bridge was destroyed by Simon de Montford.

Portion of an Elm pile (sound) which formed part of the second bridge on the Medway at Rochester, driven in about the year 1280, and taken up in the year 1870.

The above three specimens were exhibited to illustrate the fact that timber, deeply immersed and covered with water, will endure unprepared during many ages.

Specimen of Fir timber, forming part of a tank disintegrated by a solution of sodium sulphate. The encrusting matter between the concentric rings had been entirely dissolved and removed, so that the rings disintegrate and separate from each other in flakes.

Specimen of wood destroyed by drippings of sulphuric acid. This timber had the appearance of having been carbonized as if by fire.

These two specimens exhibited to show the destructive influence upon wood of various chemical agents.

Two specimens of timber injected, first with natrium and afterwards with creosote oil.

Three specimens of timber injected, first with a solution of copper sulphate and subsequently with creosote oil.

These five foregoing specimens were exhibited to illustrate a theory as regards the preservation of mummies, and also to illustrate the fact that timber can be injected, first with metallic salts and next with oils of tar.

Series of specimens of successful creosoted timber, contributed from various sources, to illustrate the duration of creosoted timber during long periods. All these specimens were perfectly sound.

Portion of a half-round fir sleeper laid in the East Suffolk line in 1858, taken up in 1882.

Portion of a half-round fir sleeper, fifteen years in the ground, from the Mid-Kent line of the South Eastern Railway Company.

Portion of a rectangular fir sleeper, fifteen years in the ground, from the Great Western Railway Company.

Portion of rectangular fir sleeper, twenty years in the ground (specimen C), contributed by the London and North Western Railway Company.

Portion of fir sleeper, twenty-eight years in the ground (specimen H), contributed by the London and North-Western Railway Company.

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Portion of rectangular fir sleeper, thirty-two years in the ground (specimen M), contributed by the London and North-Western Railway Company.

Portion of rectangular fir sleeper, fifteen years in the ground (specimen O), contributed by the London, Chatham and Dover Railway Company.

Portion of a post belonging to a fence from the Victoria Docks, after twenty-nine years' duration, contributed by Messrs. Burt, Boulton and Haywood (specimen G).

Portions of the preceding specimens had been analyzed at the Author's laboratory at Silvertown, as mentioned in the Paper. These also form portions of the specimens analyzed by Mr. Greville Williams.

Specimens of products derived from coal to illustrate the diagram, Plate 6.

Name.	Formula.
Coal tar	..
Gas liquor	..
Sulphate of ammonia	$(NH_4)_2SO_4$
Crude naphtha	..
Once-run naphtha	..
Benzol commercial	..
Benzol pure	C_6H_6
Nitrobenzol	$C_6H_5NO_2$
Aniline	C_6H_7N
Toluol commercial	..
Toluol pure	C_7H_8
Nitrotoluol	$C_7H_7NO_2$
Toluidine	...
Xylol	C_8H_{10}
Nitroxylol	$C_8H_9NO_2$
Cumol	C_9H_{12}
Best solvent naphtha	..
Pyridine	C_5H_5N
Carbolic acid crude	..
Carbolic acid pure	C_6H_6O
Picric acid	$C_6H_2(NO_2)_3OH$
Aurin	$C_{20}H_{14}O_3$
Cresylic acid	C_7H_8O
Creosote	..
Creosote salts	..
Naphthalene in albocarbon form	$C_{10}H_8$
Naphthalene pure in sublimed form	$C_{10}H_8$
Naphthalene pure in crystallized form	$C_{10}H_8$
Nitronaphthalene	$C_{10}H_7NO_2$

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Name.	Formula.
Naphthylamine	$C_{10}H_7NH_2$
Naphthol	$C_{10}H_7OH$
Phthalic anhydride	$C_8H_4O_3$
Quinoline	C_9H_7N
Phenanthrene	$C_{14}H_{10}$
Phenanthrene quinone	$C_{14}H_8O_2$
Carbazol	$C_{12}H_9N$
Anthracene oil	..
Green oil	..
Anthracene pressed	..
Anthracene pure	$C_{14}H_{10}$
Anthraquinone commercial	..
Anthraquinone crystallized	$C_{14}H_8O_2$
Anthraquinone sublimed	$C_{14}H_8O_2$
Alizarine in paste	..
Purpurine in paste	$C_{14}H_8O_5$
Alizarine sublimed	$C_{14}H_8O_4$
Acridine	$C_{12}H_9N$
Pyrene	$C_{16}H_{10}$
Pyrene quinone	$C_{16}H_8O_2$
Chrysene	$C_{18}H_{12}$
Chrysoquinone	$C_{18}H_{10}O_2$
Pitch	..

Heavy tar acids extracted from green oil.
Heavy tar oil extracted from old creosoted woods.
Anthracene " " "
Naphthalene " " "

Scotch creosote.

Specimens of substances not derived from coal tar, to illustrate Table 2.

Bone oil.
Olive oil.
Palm oil.
Cotton seed oil.
Linseed oil.
Resin oil.
Paraffin oil.
Shale oil.
Creosote from wood.

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APPENDIX 7.

August 1883.

REPORT OF DR. C. MEYMOTT TIDY, M.B., F.C.S.

ON THE DESCRIPTION OF CREOSOTE BEST SUITED FOR CREOSOTING TIMBER.

To the Directors of the Gas Light and Coke Company.

Gentlemen,—In accordance with instructions I received from you to consider and report on the character of creosote best suited for creosoting timber, I have, during the past fifteen months, devoted a considerable amount of attention to this question, and made numerous experiments thereupon. I now beg to report the results of my investigations.

Let me define, first of all, exactly what I understand by the word "creosote." This is important, seeing that it does not imply a compound of fixed chemical composition. It is in fact a composite liquid, made up of a variety of chemical bodies in different proportions, the quality depending (first) on the kind of coal from which the coal tar is obtained, and (secondly) on the details of the distillation and treatment.

Broadly speaking, I mean by the word creosote a product of the distillation of coal tar after it has reached a temperature of about 300° Fahrenheit, in other words, after what is known as the light oil has distilled over.

It may be taken that about one-third the bulk of the tar consists of the "creosote" or "heavy oil" employed in creosoting timber.

The process of creosoting is effected by placing well-weathered wood in a vessel so constructed that a more or less perfect vacuum may be obtained. The creosote, heated to a temperature of from 100° to 120° Fahrenheit, is allowed to pass into the exhausted reservoir, and thus finds its way into the pores of the wood.

The advantages to be derived from the process are, I consider, of a *threefold* nature, and I give them in what appears to me to be the order of their importance:—

1stly. *A physical action.* A very greatly increased solidity is effected by choking up the pores, thus agglutinating the whole mass of the wood into a more or less solid block. Apart from its rendering the wood more solid, this physical action is important in preventing the subsequent absorption of moisture.

2ndly. *A physiological action.* The smell of the creosote imparted to the wood prevents germinal life, well known to be destructive to timber, from being developed within it. Seeing that the preservation of timber has been effected by such materials as chloride of zinc, sulphate of copper, &c., with greater or less success, and that the action of these bodies must be mainly, although I admit not entirely, dependent on their toxic properties, this physiological action is one of importance. It must be remembered, moreover, that creosote has the advantage of a well-marked smell, which odour most of the lower animals dislike. In this respect it is superior to the other bodies I have named.

Further, it is worth pointing out that all the constituents of the coal tar, and not the tar acids only, have a more or less well-marked tarry odour.

3rdly. *A chemical action.* Respecting the chemical action, I would draw attention to the fact that tar-acids are not only antiseptic, but that they possess the power of coagulating albumen. It is to this latter action that I shall have

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to refer later on in this report, as playing an important part, in my opinion, in the preservation of the timber.

Having now dealt with what I conceive to be the details involved in the process of creosoting, the two following questions arise: (1st) Upon what constituents of the creosote does its value specially depend, and what are the relative values of its different constituents? (2ndly) If there be constituents in the creosote, which of themselves possess no special value, do they in any respect lessen the activity of the valuable constituents?

The importance of considering the precise value of the several constituents of creosote, arises as follows:—

Speaking generally, creosote may be divided into two classes, London and country creosotes. By London creosote we mean the creosote derived from the tars of the London gasworks, the east coast generally, and from the gasworks of towns such as Southampton, Brighton, &c., where the coal employed is Newcastle coal. So far as I am able to learn, the larger proportion of the creosote produced in England is of this character. The two creosotes, however, being very different in their composition, it becomes important to consider them separately.

The London creosote has a somewhat high specific gravity, and contains a comparatively large percentage of naphthalene, and a small percentage (*i.e.*, less than 10 per cent.) of tar acids. Further, it contains a considerable quantity of the heavier portions of the oil, that is, of those portions not volatile at a temperature below 600° Fahrenheit.

The Country creosote, on the other hand, has a less specific gravity, and is considerably more fluid than London creosote. It contains considerably less naphthalene than the London creosote, a larger total percentage of tar acids, and a smaller percentage of the heavier portions of the oil present.

The real question I have had in view in this inquiry being country creosotes *v.* London creosotes, it became necessary to inquire the relative values of the heavier portions of the oil, of the naphthalene, and of the tar acids in creosoting. In view of making what I have to say clear, I may venture to place before you what I conceive to take place in the operation of creosoting.

The creosote, having been sufficiently heated to bring the whole of the suspended constituents into a perfectly liquid condition, is driven into the wood, from which the air has been more or less completely exhausted. The tar acids, in the first instance, effect the coagulation of the albumen of the wood sap. This coagulated albumen mixes with the naphthalene of the creosote, which so soon as the temperature becomes sufficiently reduced is re-deposited, and forms, along with the heavier portions of the oil, a solid magma within the pores and fibres of the wood. That this formation of a solid magma actually occurs, I have convinced myself by numerous microscopic examinations of creosoted timbers.

Tar-Acids.

The success of the process, therefore, being presumably assisted by the coagulation of the albumen, the question arises, What quantity of tar-acids is necessary to effect this object?

To determine this point I have made a variety of experiments.

There is very little doubt in my mind supposing that 10 lbs. of creosote per square foot be injected into the wood, and that the timber be of the kind ordinarily used (although in this respect different kinds of wood do not differ so much as might be supposed), that 2, or from that to 3, per cent. of tar-acids would amply suffice to effect this coagulation of the sap albumen.

We are now led to consider if any value, and if any, what value, is to be

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ascribed to the tar-acids beyond that needed to effect the coagulation of the albumen.

I am far from prepared to say they are otherwise entirely valueless. Still it is a remarkable fact I have over and over again verified, that in the timbers that have been creosoted for a considerable time (say a year) very small quantities indeed (if any) of free tar-acids are to be found.

I have upon this point instituted a series of examinations of sleepers obtained from independent sources, and of ages varying from one to twenty years, and it is a fact worth noting that within a very short time after a sleeper has been in use the tar acids appear to be entirely dissipated.[1]

Seeing, however, that the life of a sleeper is by no means so limited, the facts I have mentioned suffice to show that the action of the tar acids *per se* cannot have any very great or permanently preservative influence in creosoting.

I admit it was natural to suppose that bodies, commonly regarded as powerfully antiseptic, should have been the active agents in the process. Further I must admit that it was with such view I commenced this inquiry. My recent investigations, however, have clearly shown that the value of the tar-acids in the creosoting process has been greatly over-estimated.

I am convinced that so long as the quantity of carbolic acid present in the creosote, is sufficient to coagulate the albumen of the wood sap, that that, for practical purposes, is sufficient.

Naphthalene.

I have now to consider the value of the naphthalene.

I am disposed to think that this body is of infinitely greater value than at first sight appears. Admitting that, as an antiseptic, it is inferior to the tar-acids, nevertheless, so far as preservative action alone is concerned, it must not be supposed to be inoperative. Its special value however consists in helping to render the wood solid.

But it may be said, granting this to be the case, naphthalene is so volatile that the heat of the sun, especially the intense heat of an Indian climate, would soon drive the whole of it off. It is true that on exposing a block of creosoted timber in an oven to a temperature of 54·5° Centigrade (130° Fahrenheit), and this may be taken to be an extreme tropical heat, the door of the oven, after a short time, shows conclusively that some of the naphthalene in the sleeper has undergone volatilization by the heat applied.

I would, however, direct attention to the following experiment:—

I exposed a large block of creosoted timber (accurately weighed) to a temperature of 65·5° Centigrade (150° Fahrenheit). On weighing this at the end of twenty-four hours, I found it to have lost 1,200 grains. On exposing the same block to the same temperature for another twenty-four hours, it lost 135 grains, whilst on continuing the exposure for a third twenty-four hours, it lost only 15 grains. After this the loss was practically nil.

I now planed off about ¼ inch of the block I had already heated. This done I again exposed it to a heat of 55·5° Centigrade (130° Fahrenheit) for twenty-four hours, during which time it lost 1,150 grains. The loss on the second day was less than 100 grains, whilst on succeeding days the loss was practically nil.

The surface of the wood was again planed off, and similar experiments repeated a third time, with almost identical results.

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[1] This report was written some time before the appearance of Mr. Greville Williams' Paper. My own results, I may say, are in entire accord with his.

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From numerous microscopical examinations of the timber, and from the experiments I have described, I consider that I am justified in drawing the following conclusions *re naphthalene*:—

1st. That supposing, for the sake of argument, naphthalene possesses no great antiseptic power, nevertheless it acts beneficially by clogging up the pores of the wood, forming a more or less solid magma with the coagulated albumen. In this way it assists the physical part of the creosoting process, upon which the preservation of the timber materially depends.

2ndly. That although a certain quantity of naphthalene would undoubtedly be volatilized by a tropical heat, nevertheless that the loss would practically be limited to the *surface* of the timber, and would be complete a day or two after exposure, the naphthalene in the deeper parts of the wood remaining fixed by incorporation with the albumen coagulated by the action of the tar-acids.

3rdly. That inasmuch as the naphthalene cannot injure the action of the tar-acids, or other constituents of the creosote, and is itself a positive benefit to the process, there is not only no object in requiring that the oil used for creosoting should be free from naphthalene, but that it would be unadvisable to demand such freedom.

There are many other facts that in my judgment corroborate the views I have expressed. Thus I am given to understand that during the twelve years after the process of creosoting was first introduced into India, the whole of the sleepers were prepared with heavy London creosote (that is, a creosote highly charged with naphthalene), with the occasional admixture of a small quantity of country oil for the purpose of dilution.

It is perfectly certain further that it was on account of the good results so obtained, that creosoting became a process of acknowledged utility.

So far as I can learn, it was not until the country oils became more extensively used, that any complaints respecting the inefficiency of the process arose. From independent inquiries, I think there is the strongest possible reason to believe that the sleepers that proved unsatisfactory had been prepared with Country, and not with London oil.

Heavy Oils.

Nothing has impressed me more strongly in the course of these inquiries than the value of the heavy oils present in the creosote, that is, of the oils that do not distil over under 600° Fahrenheit. Of a certain antiseptic power, and very difficult of volatilization, they are I believe bodies of great value in the oil employed in the creosoting process.

I have carefully examined numerous samples of the creosote supplied by your Company, and I give herewith the analysis of eighteen samples:—

(Here follows an analysis of eighteen samples, alluded to in Mr. Boulton's reply.)

After a very careful consideration of the conditions necessary to ensure the successful creosoting of timber, it appears to me that the following points need special attention:—

1. That the timber should be well dried, so that the pores of the wood may be completely pervious.

2. That the creosote should be of a heavy, rather than of a light description, *i.e.*, that it should contain oils which are given off at high temperatures, together with other matters that become solid within the timber after the creosote has been allowed to cool to a normal temperature.

3. That as much creosote should be put into the timber, as the timber can possibly be made to absorb.

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Taking into consideration the whole body of the evidence now before me, and which I have submitted to you in this report in part only, I am of opinion that no oil could be better suited than your own for the purpose of creosoting timber, and I would suggest the following as a specification for creosote that would, in my judgment, ensure to engineers and others interested in the process, the best possible results:—

1. That the creosote should be completely liquid at a temperature of 100° Fahrenheit, no deposit afterwards taking place until the oil registers a temperature of 93° Fahrenheit.

2. That the creosote shall contain at least 25 per cent. of constituents that do not distil over at a temperature of 600° Fahrenheit.

3. That, tested by the process hereafter to be described, the creosote shall yield a total of 8 per cent. of tar-acids.

There are certain details connected with this specification to which I desire to draw attention.

1. The omission of any clause specifying the specific gravity of the creosote to be used. I have done this advisedly, because of the extreme difficulty in taking the gravity of creosote at normal temperatures with the 1,000 grain bottle, and the practical uselessness in my judgment of employing a hydrometer for the purpose. If it be considered necessary to introduce a specific-gravity clause, I would suggest that the gravity be between 1,040 and 1,065, water being 1,000. I am of opinion, however, that for practical purposes a specific gravity clause is altogether unnecessary.

2. Believing strongly as I do in the value of those constituents of the oil that are the most difficult to volatilize, I have deemed it right to suggest a clause to the effect that the creosote shall contain at least 25 per cent. of matters that distil over above 600° Fahrenheit.

3. I have made a large number of experiments as to the best method by which the estimation of the tar-acids may be determined.

I note—

(*a*) That very slight differences in the strength of the solutions used, and in methods of manipulation, considerably influence the results obtained. I therefore deem it necessary that as a part of the specification, the process to be employed for estimating the acids should be exactly stated.

(*b*) I have failed to discover any easy method of separating the carbolic from the other tar-acids. I have tried for this purpose numerous experiments, but with such unsatisfactory results, that I have decided to recommend that the total quantity of tar-acids only should be stated. Further, the fact that as preservatives one kind of tar-acid is, so far as we know, as good as any other, renders a further separation of the acids in my judgment unnecessary. My analyses of samples will show that in fixing not less than 8 per cent. of total tar acids, we obtain a fair index of the purity and genuineness of the creosote.

I shall be happy, if the Board wish it, to enter into further details upon such points as they may deem desirable.—I have the honour, gentlemen, to remain, your obedient servant,

(Signed) C. Meymott Tidy, M.B., F.C.S.,
Professor of Chemistry and of Forensic Medicine at the London Hospital; Medical Officer of Health for Islington; late Deputy Medical Officer of Health for the City of London; Official Analyst to the Home Office, &c., &c.

3, Mandeville Place, Manchester Square, W.

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Dr. Tidy's Specification for Creosote.

1. That the creosote shall be completely liquid at a temperature of 100° Fahrenheit, no deposit afterwards taking place until the oil registers a temperature of 93° Fahrenheit.

2. That the creosote shall contain at least 25 per cent. of constituents that do not distil over a temperature of 600° Fahrenheit.

3. That, tested by the process hereafter to be described, the creosote shall yield a total of 8 per cent. of tar-acids.

Process to be adopted for determining the Coal Tar-Acids.

1. 100 c.c. of the well mixed creosote is to be distilled at a temperature of 600° Fahrenheit until no further distillate comes over. The distillate so obtained, is to be mixed and well shaken in a stoppered flask with 30 c.c. of a solution of caustic soda, having a specific gravity of 1,200, water being 1,000. The mixture is then to be heated. This done, the stopper is to be replaced in the flask, and the hot mixture again shaken vigorously for at least a minute.

The contents of the flask are now to be poured into a separating funnel and the soda solution drawn off. The creosote is to be heated a second and a third time in a similar manner with the caustic soda solution, except that only 20 c.c. of the soda solution shall be used for the second and third extractions, instead of 30 c.c., as in the first extraction.

2. The three soda solutions are now to be mixed together. *When cold* any particles of creosote are to be got rid of by means of a separating funnel. This done, the solution is to be thoroughly boiled in order to expel the last traces of creosote present in the solution. The mixture is then to be allowed to cool. When cold, dilute sulphuric acid (1 of acid to 3 of water) is to be added (about 35 c.c. will be required) until the solution becomes slightly acid to litmus. The whole is then to be poured into a separating funnel, and allowed to stand until perfectly cold, and the tar-acids well separated.

3. The tar-acids are now to be dissolved in 20 c.c. of the caustic soda solution (specific gravity 1,200), and 10 c.c. of water. The mixture is then to be boiled and filtered through a funnel fitted with a plug of asbestos. The asbestos plug is to be washed with not more than 5 c.c. of boiling water. The solution is to be allowed to cool *perfectly* in a 100 c.c. measure. It is then to be rendered slightly acid with dilute sulphuric acid (1 to 3), (10 c.c. will probably be found sufficient for this purpose). The whole is again allowed to stand *for two hours* until *perfectly cold*, when the percentage of the tar-acids is to be read off.

Process to be adopted in estimating the quantity of Distillate.

The operation is to be conducted in a retort (fitted with a thermometer) immersed in an oil or hot-air bath. The heat at first is to be low, and the temperature gradually raised to 600° Fahrenheit, and continued until no further matters distil over.

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APPENDIX 8.

Correspondence between Mr. Boulton and the Gas Light and Coke Co.

Attention has been directed to the fact that there is appended to Dr. Tidy's report to the Gas Light and Coke Co. an analysis of eighteen specimens of creosote oils manufactured by that company, and that these creosotes do not represent the type of creosote recommended by Dr. Tidy himself.

It has been assumed that this list represents the average type of London creosotes. This, however, is not the case, as the typical London creosotes do not contain so large a quantity of tar-acids, and are of a heavier specific gravity, and distil at a higher boiling-point than the eighteen specimens in question.

The following correspondence will explain the matter:—

Copy of letter to the Gas Light and Coke Co.

"64, Cannon Street, London, E.C., May 22nd, 1884.

"J. Orwell Phillips, Esq., Secretary,
"Gas Light and Coke Co., Horseferry Road.

"Dear Sir,—In my Paper on the 'Antiseptic Treatment of Timber,' recently read at the Institution of Civil Engineers, and with reference to the heavy oils derived from the tars of the London district, I stated that those oils did not, as a rule, contain more than from 4 to 7 per cent. of tar-acids as they came from the still. This fact I derived from a very considerable experience in distilling the tars of various companies, including those of your Co. previous to the erection of tar-distilling apparatus at your Beckton works.

"On mentioning this to your representative, Mr. Blagden, yesterday, he stated that on your present manufacture your average of tar-acids was 6 per cent., which agrees with my previous experience.

"If your Board confirms this, I shall be much obliged if they will authorise me to send it in as statistical information to be included in the Appendix to my Paper. This does not, of course, interfere with the fact that these creosotes can have their proportion of tar-acids raised by removing some of the heavier portions of the oils, as was the case with the samples tabulated in Dr. Tidy's printed report to your Co., dated August 1883.—I remain, dear sir,

"Yours very truly,
"(Signed) S. B. Boulton."

Copy of letter received from the Gas Light and Coke Co. in reply to the above:—

"The Gas Light and Coke Co.,
"Horseferry Road, Westminster, May 23rd, 1884.

"Dear Sir,—The Directors have not the least objection to the statement contained in your letter of the 22nd inst., and you are perfectly at liberty to express their concurrence in it.—Faithfully yours,

"(Signed) J. O. Phillips, Secretary.

"S. B. Boulton, Esq., 64, Cannon Street, E.C."

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APPENDIX 9.

On Disinfection, by Dr. Robert Koch.

Mittheilungen des kaiserlichen Gesundheits-Amtes. Berlin, 1881.

Condensed translation by D. Bendix.

In consequence of the defective knowledge of infectious substances, and the circumstance that these substances have not yet been classified and organized, it was not possible to investigate with satisfaction the activity of the various disinfecting agents which have been proposed from time to time. According to the present standing of science, it would be necessary to subject a disinfectant successively to all the infectious substances against which it is proposed to use it.

To test the action of disinfectants on micro-organisms only would not be correct, as a number of the infectious substances have not yet been recognized as micro-organisms, and it is therefore necessary to include also the non-organized ferments in investigating this action. It would furthermore be unreasonable to choose only such disinfectants as will satisfy all the conditions under which it is proposed to disinfect the substance.

In order to ensure disinfection, it is requisite to use the disinfecting agent within the range of its safe sphere of activity, and not to subject it to requirements which, from a chemical and physical point, it cannot fulfil. It therefore becomes necessary, in testing a disinfectant, to take into consideration the conditions under which it is proposed to use the same in practice. The question at what stage can the action of a disinfectant be regarded as sufficient can be answered only in one way, viz., the action is considered complete when all vitality and the germs from which new life is again developed have been completely destroyed; for instance, disinfecting agents which are not capable of completely destroying fungi cannot be used for the disinfection of objects which are infected by skin diseases. In a similar manner, a disinfectant which allows bacteria and their spores to live cannot be employed for diseases in which bacteria have been proved to cause the disease. Such diseases, in consequence of their number and importance, occupy the first place among the infectious diseases; it therefore becomes necessary, in examining a disinfectant, to test its action on bacteria and their spores. If it proves wholly ineffective, it should be struck out of the number of the ordinary agents used for destroying infectious diseases. In special cases, however, it may be still active. It should further be observed whether the agent affects the ordinary form of bacteria and also the spores, and unless it is active in the latter case also it cannot be regarded as fulfilling all its requirements. In order to test the final action of the disinfectants employed, the Author in his experiments used cultivated bacteria such as are not often found, as contaminating the atmosphere.

In judging of the capability of development the objects of disinfection were tested on a solid nutritive substance (boiled potatoes, nutritive gelatine, &c.). In testing the action of a disinfectant the following points should be taken into consideration; it should be ascertained whether the agent is able to kill all organisms; for this it suffices to prove that the spores of bacilli have been killed, as formations of greater resisting power are not yet known. It is, however, necessary to test the action of the disinfectant in destroying micro-organisms, and also its power of arresting their development in suitable nutritive solutions; finally, it is necessary, in order to obtain a safe result, to take into

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account the concentration of the disinfectant, the duration of the action, the influence of solvents, temperature, &c., &c.

Referring to the action of carbolic acid in arresting the development of the spores of splenetic fever germs, the Author mentions that it is very slight; that even after five days' action of a 2 per cent. solution of carbolic acid the spores show distinct signs of vitality, and a 1 per cent. had no perceptible action on the spores even after fifteen days. As, however, the practical utility of a disinfectant is dependent upon the rapidity with which it acts, and, as in the case of carbolic acid, rapid action takes place only when concentrated solutions are used, the value of carbolic acid is much limited as a germicide. For the destruction of spores it is altogether useless, being almost without action. In cases, however, where it is desired to destroy micro-organisms free from spores it may be used with advantage, and it is in consequence of this circumstance that carbolic acid owes its reputation as a disinfectant. The experiments, which have been conducted with a view to determine the disinfecting value of carbolic acid, showed that 1 gram of pure carbolic acid is able to completely prevent the development of splenetic fever bacilli in 850 cubic centimetres of a nutritive solution; moreover 1 gram of carbolic acid in 1,250 grams of nutritive solution perceptibly prevents their development. These numbers apply only to splenetic fever bacilli; other bacteria are influenced by carbolic acid in a less degree.

In determining the activity of carbolic acid in a gaseous form, in which, according to Von Scholte and Gaertner, it is effective when 15 grams are vaporized per cubic metre of the air, it is questionable whether the small amounts of carbolic acid which are volatilized at the ordinary temperature, if allowed to remain in contact for some time with the objects to be disinfected, would not exhibit the same disinfecting action. The experiments which have been made in this direction have shown that the vapour of carbolic acid which is given off at the ordinary temperature is quite unable to influence the germinating power of the spores of bacille even after six weeks' action. At an elevated temperature, however, the vapour of carbolic acid proves to be more active. At 55° Centigrade many of the spores were destroyed after half an hour's action; after three hours but little germinating power remained, and after five to six hours the destruction of all germs was completed. Disinfection with the vapour of carbolic acid can, however, be of practical utility only if the action be completed in half an hour. It is not possible, however, to obtain this result even by the application of an elevated temperature. It therefore becomes necessary to abandon the use of carbolic acid vapour for the disinfection of large objects. Other disinfectants behave like carbolic acid at an elevated temperature. The preceding experiments have reference only to aqueous solutions of carbolic acid, the results of the experiments made with other solvents were very remarkable, inasmuch as they showed that solutions in oil or in alcohol do not exhibit the slightest antiseptic action. This remarkable coincidence was noticed also with other substances, such as salicylic acid, thymol, &c. If, however, carbolic oil is brought into contact with watery substances—for instance, the tissues of the human body, wounds, &c.—a portion of the carbolic acid is undoubtedly given up, and in this case it is possible to observe signs of antiseptic action. By taking into consideration the circumstance that a 1 or 2 or even 5 per cent. solution of carbolic acid fails to exercise any perceptible influence on the spores of bacteria during the short period of an operation, and that, in order to arrest the growth of bacteria in a solution, the carbolic acid must be permanently present in the proportion of 1 to 400, it is not surprising to find bacteria in Lister's dressings, in spite of the careful way in which they are prepared.

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The experiments which have been made on the disinfecting property of sulphurous acid have also given a remarkable result. It has been found that when sulphurous acid is allowed to act on dry objects, or in the presence of water or steam, it does not possess any real disinfecting value. The action of aqueous solutions of sulphurous acid on the spores of splenetic fever germs is comparatively small; if, on the contrary, the objects to be disinfected are moistened before treatment with sulphurous acid, the activity becomes greater. All experiments, including those which have been made under the most favourable conditions, have shown that sulphurous acid is not a destroyer of all germs of organic life. Sulphurous acid must therefore be regarded as a disinfectant whose action is uncertain; the same applies also to the double sulphite of lime, which is frequently used as a substitute for sulphurous acid.

The third disinfectant included in the Author's investigation was chloride of zinc. It is said that the action of this substance can be depended upon in 1 per cent. solutions. The result of these experiments showed, however, that a 5 per cent. solution of chloride of zinc did not affect the development power of the spores of splenetic fever germs which had been placed in the same for one month. It is not even possible to speak of chloride of zinc possessing the property of perceptibly arresting the development of bacteria.

The preceding investigations have shown that three of the substances hitherto mostly employed as disinfectants in no way correspond with the expectations put upon them. The disinfecting value of carbolic acid is far smaller than has been assumed hitherto, whilst sulphurous acid has proved to be unreliable, and chloride of zinc perfectly useless. In consequence of this the disinfecting value of a further series of agents was investigated, the substances employed being those which had already been recommended as disinfectants or probably possessed disinfecting properties. It was observed in most cases that the oily as well as the alcoholic solution was of no action, whilst the aqueous solution was active to a greater or less degree. It may be added that glycerine, like alcohol, fails to have the slightest action on the spores of splenetic fever bacilli. It has already been remarked that the disinfecting agent to be of practical utility should not merely be reliable but also quick in its action; in practice, the time of action should not exceed more than twenty-four hours, otherwise the operation becomes either troublesome or impracticable. Again, in practice only such agents are of use which destroy all germs of organic life within a period of twenty-four hours. From a long series of substances experimented with, only corrosive sublimate, osmic acid, and permanganate of potash, have fulfilled the above requirements, in addition to chlorine, bromine and iodine. Permanganate of potash, however, only acts when the solution contains 5 per cent. A series of experiments was made also in reference to the action of arresting the development of germs. Both series of experiments showed that only a few substances are of practical value as disinfectants. If the difference between these agents, which completely destroy the vital energies and those which arrest development, is upheld, chlorine, bromine, and corrosive sublimate, belong to the first category, whilst corrosive sublimate, ethereal oils, thymol, and amyl alcohol belong to the second category.

Experiments have been made to test the value of bromine and corrosive sublimate for special cases. For the disinfection of closed rooms, bromine may be employed: it is necessary, however, that the disinfectant remains in contact with the walls for as long a period as possible. On the whole, however, the disinfection with bromine would be too expensive an operation.

With regard to corrosive sublimate, it is surprising to find that the powerful

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action which this agent possesses has not been utilized to a larger extent. Corrosive sublimate is the only disinfectant which acts rapidly after the first application, and without any preliminary treatment of the objects to be disinfected. Its strongly poisonous properties only have prevented it from being used on a large scale. It must, however, be borne in mind that it is not necessary to allow the disinfecting agent to remain permanently on the object to be treated, and that it can be removed after a short time by repeated washings with water. The disinfection by means of corrosive sublimate is not, however, suitable for a continuous process, as in the disinfection of liquids precipitates are formed which, on repeated disinfection, accumulate, and in consequence of the presence of large quantities of mercury may give rise to injurious effects.

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APPENDIX 10.

CONTRIBUTIONS TO THE STUDY OF ANTISEPTICS. By F. BOILLAT.

(Journal für praktische Chemie, vol. xxv., pp. 300–309.)

Translation.

The researches recorded in this Paper were undertaken on account of the appearance of a pamphlet on disinfection by Dr. R. Koch. Koch states therein that of the substances at present employed as antiseptics, the only ones worthy of the name are chlorine, bromine, iodine, corrosive sublimate, with possibly potassium permanganate and osmic acid. This contradiction of generally-accepted facts is not, however, considered as strong as it appears. In medicine, and more especially in surgery, it is sufficient if the antiseptic employed is capable of preventing the formation of micro-organisms, which are detected by examining the wound and its secreted matter under the microscope, and if the propagation of organisms is arrested for a time long enough to allow the wound to heal, the antiseptic has fulfilled all its requirements. It has, however, never been determined why, by the use of a particular antiseptic, putrefaction and the development of micro-organisms is prevented, and it has been supposed in general that the substance destroys germs or arrests their propagation. It is evident, however, that substances such as phenol, chloride of zinc, acids, corrosive sublimate, ethereal oils, &c., all of which differ in chemical constitution, cannot possibly act on the vitality and development of bacteria in the same destructive manner. Moreover, a number of these micro-organisms, *e.g.*, the splenetic-fever germs, form spores which, as may be expected, resist the action of antiseptics very powerfully. As soon as inquiries are made into the injurious effects of antiseptics on the development and vitality of organisms and their spores, it immediately becomes necessary to subject antiseptic agents to a proper classification. Koch, who has investigated the action of various antiseptics on definite species—*Monas prodigiosa* and *Bacillus anthracis*—by allowing the micro-organisms under examination to remain in the antiseptic medium for a longer or shorter period, and subsequently introducing them into a suitable nutritive solution, and regarding the appearance or non-appearance of their development and propagation as a criterion of their vitality, must necessarily have arrived at a different opinion with regard to the efficacy of many antiseptic substances. On reading through his work, however, one readily conceives that even his mode of judging the value of an antiseptic is one-sided. For instance, the spores of the splenetic-fever organism, after being preserved for many days in a 1 per cent. aqueous solution of phenol, or in a 5 per cent. solution of calcium chloride, do not lose their capability of development; their propagation is, however, arrested, and this is of great importance for medical purposes, for although substances like chlorine, bromine, acids, &c., would effectually destroy bacteria and their spores, they would in most cases, when applied in the same, or even in less concentration, destroy the tissues of animal organisms. The application of such substances for the treatment of wounds is therefore not practicable. Until it is possible to find a specific poison for germs which will not injure the human organism, the antiseptics employed for the treatment of wounds will be those which are more or less injurious to the animal tissues, but severely injure the vitality of micro-organisms, *i.e.*, arrest their development. The use of destructive disinfectants, such as alkaline solutions, acids, &c., is adapted only, and that to a limited extent, to the preservation of lifeless objects. This explains why, *e.g.*, chloride of zinc, although it does not kill the spores of the splenetic-fever germs

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in a 5 per cent. solution, is nevertheless a good antiseptic agent. Koch erroneously asserts that chloride of zinc does not possess the property of arresting the development of bacteria.

Most antiseptics are characterized by the circumstance that they coagulate dissolved albumen, forming permanent insoluble compounds therewith. On treating blood serum or egg albumen with a dilute solution of sulphate or chloride of zinc, Lieberkühn's zinc albuminate having the composition $C_{72}\ H_{112}\ N_{18}\ S\ O_{22} + Zn\ O_2\ H_2$, and containing 4·74 per cent. zinc, is formed. A similar reaction occurs when the wound is treated with the solution of a metallic salt. That chloride of zinc, corrosive sublimate, chloride of iron, &c., do not remain as such on the surface of the wound, but combine with the albumen of the tissues, there is no longer a doubt. In order to determine how far these metallic salts, when placed on wounds or brought into contact with albumen, act as antiseptics, it is necessary to investigate the behaviour of micro-organisms on such albuminous metallic precipitates. Such experiments have, to my knowledge, never been made, and at the suggestion of Professor Nencki I have undertaken this work in the interest of a rational study of antiseptics.

Samples of blood serum and egg albumen, the latter diluted with three or four times its weight of water, were treated with an excess of solutions of phenol, chloride of zinc, sulphate of copper, and corrosive sublimate, and the resulting precipitates washed on filters until the wash-water was free from the precipitant; 2 or 3 grams of the moist precipitate was then made up with water to a thin paste, and allowed to remain at the ordinary temperature, loosely covered with a bell-glass. Watch glasses, containing fresh blood serum and Koch's nutritive gelatine, served to control the experiments. The results of these experiments are shown in the following Table:—

Albuminates.	Time after which the first Micro-organisms were observed. In Days.	Time after which putrefaction and bad smell were observed.	Remarks.
1. Serum	1	2	After the fourth day fungi appeared, which grew rapidly, covering the whole substance after ten days.
2. Nutritive gelatine .	1	4	
3. Phenol albumen serum	2	6	
4. Phenol albumen (white of egg)	2	6	
5. Copper albumen . .	28	40	After forty-six days the substance which had been light blue, changed and gave up the blue to the water. After thirty-one days fungi appeared which covered the whole of the substance in fifty-four days.
6. Zinc albuminate serum	31	46	After fifty-four days the substance assumed a dark colour and strongly putrid smell.
7. Zinc albuminate (white of egg)	31	46	Ditto.
8. Mercury albumen serum	42	60	No fungoid growth.
9. Mercury albumen (white of egg)	45	60	Ditto.

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In a second series of trials the same metallic albuminates (prepared from blood serum) were sown with a green coccus found on an infusion of coffee. It consisted of cocci of an average diameter of 1·0 micro-millimetre, partly isolated and partly joined together in masses:—

Albuminates.	Time after which the sown Fungus showed a distinct increase. In Days.	Remarks.
1. Nutritive gelatine .	2	
2. Copper albumen . .	No growth	Even after the lapse of four weeks it was not possible to detect either mucroscopically or microscopically an increase of the inocculated places.
3. Zinc albuminate . .	"	
4. Mercury albumen. .	"	

In a third series of experiments splenetic-fever germs were dried on silk threads and brought into contact with the metallic albuminates.

Albuminates.	Time at which the Spores of splenetic-fever germs grew to threads. In Days.	Remarks.
1. Nutritive gelatine .	1	
2. Copper albumen . .	No growth	Even after four weeks no growth of the spores was observable.
3. Zinc albuminate . .	"	
4. Mercury albumen. .	"	

The same experiment was repeated with splenetic fever bacilli. The latter rapidly shot out of the nutritive gelatine in threads, which contained spores within the space of from three to four days. On the metallic albuminates, however, it was impossible to observe growth of any kind. From these experiments the following conclusions may be drawn:—

1. The substances serving to control the first series of experiments exhibited fungoid growth in twenty-four hours, and showed distinct signs of putrefaction in from two to four days. The green micro-cocci, sown with nutritive gelatine, in the second series of trials increased perceptibly in two days, whilst the spores in the control substances of the third series of experiments had grown into threads.

2. The albumen precipitated by phenol, and subsequently washed, became putrid in the first series of experiments in forty-eight hours. This coincidence, remarkable on account of the permanency of the metallic albuminates, is explained in a simple manner. The coagulum of albumen produced by carbolic acid, when washed completely with water, was perfectly odourless, and on heating a large quantity of it with dilute sulphuric acid in a retort to the boiling-point, the distillate was perfectly free from phenol when tested with bromine. It is possible, therefore, to completely wash out the phenol from the phenol albumen precipitate, and this explains why the phenol albumen, like the substances used to control the experiment, had become putrid.

3. The copper, zinc, and mercury albuminates proved to be unfavourable

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nutritive agents for micro-organisms. They would probably resist putrefaction for an unlimited period if they were not exposed to the action of atmospheric oxygen and water, by which action they appear to undergo gradual decomposition. It is an interesting fact that the antiseptic action of the inorganic metallic salts is the same as that of the corresponding albumen compounds. Mercuric chloride being the most powerful antiseptic, albuminate of mercury also resists putrefaction for the longest period.

My experiments explain the differences of opinion which exist between the statements of those authors who consider chloride of zinc a valuable antiseptic and the experiments of Koch, according to which he fails to realize why chloride of zinc has ever received the name of a disinfectant. The metallic salts, when introduced into albuminous nutritive solutions or placed on wounds, immediately produce metallic albuminates, which compounds, although *per se* not poisons for germs, are no longer suitable for their nutrition, so that if, *e.g.*, chloride of zinc is placed on the wound, or introduced into the nutritive solution in sufficient quantity to convert the whole of the albumen into zinc albuminate, the latter would resist decomposition by fungoid matter for a long time. Thus, *e.g.*, Amüat, in his experiments for preventing the putrefaction of pancreas, used, for 30 grams of the latter, 300 grams of a 1 per cent. solution of chloride of zinc. There is no doubt that the 3 grams of chloride of zinc employed were more than enough to coagulate the albumen contained in 30 grams of new glanders. In order to test the action of chloride of zinc in arresting the development of germs, Koch made the following experiment. He added to 10 c.c. of the serum of blood a solution of chloride of zinc, so that the total liquid contained 1 per cent. of chloride of zinc; a second quantity of serum was treated so as to contain 5 per cent. of chloride of zinc in the total solution. Silk threads, with the spores of the splenetic-fever organism, were then introduced into the solutions and examined under the microscope. After the lapse of twenty-four hours the spores contained in both vessels had grown to threads, their vegetation having been the same as that observed with the substances serving to control the tests. It is not stated whether the quantity of chloride of zinc employed was sufficient to precipitate the whole of the albumen and retain an excess of chloride of zinc in solution. If, however, as appears probable, the quantity of chloride of zinc was only large enough to throw down the whole of the albumen contained in the serum, the experiment has no meaning. The chloride of zinc is decomposed into hydrochloric acid and zinc albuminate, and it is easily conceivable that the spores have grown to threads, having found enough nourishment in the unprecipitated portion of the albumen, and in the remainder of the constituents of the serum. From a similar reason corrosive sublimate, which, according to the researches of Buchholtz, surpasses all other antiseptics when added to solutions of albumen, is converted into mercury albuminate, and no longer possesses the same antiseptic properties which characterize chloride of mercury. Koch injected 1 gram of a 1 per cent. solution of corrosive sublimate into a Guinea pig, and innoculated it on the same day with splenetic fever bacilli. The next day the innoculated places were much reddened and swollen. The Guinea pig then received, on the morning of the second day, 2 grams of the same solution of corrosive sublimate. According to Koch's estimation, this quantity would be sufficient to prevent the growth of bacilli in a nutritive solution equal in weight to the whole body of the animal experimented with. The animal nevertheless died, during the following night, from splenetic fever. The explanation of this is very simple. The 3 milligrams of corrosive sublimate injected into the pig were sufficient to convert only a small portion of the soluble albumen into

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mercury albuminate. As the latter is readily soluble in an excess of albumen, and also in solutions of common salt, and is not a direct poison for micro-organisms, the injected solution of corrosive sublimate could not exercise any influence over the innoculated splenetic-fever bacilli.

In the course of my investigations I have tested the antiseptic action of another antiseptic agent, the use of which for surgical purposes, although considerable at first, has been abandoned, viz., iodoform and the chemical compounds related thereto. As the pancreas and the liver of animals contain large quantities of micro-organisms, and the soluble ferments contained in the glands of the stomach promote putrefaction, I used the pancreas of oxen, as being the most reliable criterion of testing these substances for their capability of arresting the development of germs. 20 grams of pancreas and 2 grams of iodoform were added to 100 grams of water; the mixture was well shaken, and allowed to stand at a temperature of from 35° to 38° Centigrade. The whole had a strong odour of iodoform. After twenty-four hours' standing the pancreas became putrid, as though it had been in pure water. The experiment was then repeated with the following modification: 10 grams of perfectly fresh pancreas was intimately mixed with 2 grams of iodoform, and treated with enough water to cover it and prevent it from drying. The temperature was 35° to 38° Centigrade. After the lapse of twenty-four hours this mixture became as putrid as the first. As, according to the opinions of most experimentalists, iodoform, when applied to wounds, acts as an antiseptic, inasmuch as it is gradually decomposed with the liberation of iodine, and the latter is the real active agent, I tried to replace the iodoform by carbon tetrioxide, $C\,I_4$, a substance prepared a few years ago by Gustavson. Its preparation in a pure form and on a large scale was, however, very troublesome. I have, on the other hand, examined the antiseptic action of the three carbon chlorides, viz., carbon dichloride ($C_2\,Cl_4$), carbon hexachloride ($C_2\,Cl_6$), and carbon tetrachloride ($C\,Cl_4$). Experiments were made also with the two bromotoluenes—the solid and liquid—with pyrogalloldimethylether and paracresol. The results, which are illustrated in the subjoined Table, show that cresol only arrests the development of fungoid germs, its action being equal to that of phenol. The other substances, which were used in the proportion of 1 to 100 of water, were perfectly inactive. In these experiments 20 grams of pancreas were treated with 100 grams of water, and digested with the substance under examination at 35° to 38° Centigrade.

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Name of substance.	Percentage of the Solution.	Time after which Putrefaction sets in. In days.	Remarks.
Carbon dichloride C_2Cl_4 .	1·0	1	
Carbon hexachloride C_2Cl_6 .	1·0	1	
Carbon tetrachloride CCl_4 .	1·0	1	
Bromotoluene (solid) . .	1·0	1	
Bromotoluene (liquid) . .	1·0	1	
Pyrogalloldimethylether .	1·0	1	
Paracresol	0·05	1	
"	0·1	1	
"	0·2	1	
"	0·3	1	
"	0·4	1	A few threads were developed having a slightly putrid odour.
"	0·5	No putrescence	Even after eight days not the slightest trace of putrefaction is noticeable.
"	1·0	..	Large masses of tyrosin crystals were formed, which is a proof of the fact that the action of the soluble ferments on the pancreas has not been arrested.
"	2·0	..	

Laboratory of Prof. Nencki in Bern.

[DISCUSSION.

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Discussion.

Sir JOSEPH BAZALGETTE, C.B., President, said the subject of the Paper was an exceedingly practical one. Timber, in the majority of countries, was the most available material for constructive and engineering purposes, and in some countries it was almost the only material which could be used. The great defect in its use was its want of durability. Anything, therefore, which could remedy that defect, and give durability to the timber, must be a subject of great interest to the engineer. The Author in the Paper had given the result of thirty-four years' experience, together with his researches into what had been done ages before, and the whole had been placed before the members in a manner showing that he had devoted very great ability and attention to the subject. Although the Author was commercially engaged in that branch of engineering, he was sure the members would feel that the Paper had risen considerably above the commercial element, and had clearly shown that science could be, and had been, brought to bear on industrial art, so as to improve it and make it of great value. Sir Joseph Bazalgette.

Mr. BOULTON remarked that the subject of his Paper was one which had occupied his attention for many years. He hoped he had clearly explained the analytical investigations by which he had sought for some clue to what was a rather complex labyrinth, namely, the kind of substance which was the best to put into timber for its preservation. He had employed many of those substances, and the conclusion at which he had arrived was that supposing the substance to be a good antiseptic, whether, as in former times, corrosive sublimate, sulphate of copper, or chloride of zinc were used, or whether creosote oils, there was always a close connection between the durable results of the antiseptic and the immunity of that antiseptic from volatility in the air or solubility in water. Timber must be exposed to air for engineering purposes, and also to water; in some cases, in marine work, it was in the water altogether, and therefore the antiseptic ought not to be liable to evaporation or to being washed out by the action of the water. He was not there to advocate the use of the creosote of one district more than another, because, commercially speaking, that was a matter that did not affect him. He thought that all honest creosotes made from coal-tar in England were useful for the purpose of preparing timber; but he thought that some of Mr. Boulton.

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Mr. Boulton. them were more useful than others, because they were more durable. If, therefore, engineers would take the trouble to follow out his idea, and study the different constituents of the creosote oils, remembering which of them were the most durable and the least soluble, that would give a clue to the formation of fresh specifications for the preparation of timber. He did not think that the present specifications were satisfactory in all respects. Plate 6 represented the products derived from Newcastle coal, such as was ordinarily carbonized in London gasworks. There was, as had been explained in the Paper, a different series of products from the Midland coals ordinarily carbonized in other parts of the country. Taking the same coals—those carbonized in the gasworks—and subjecting them by carbonization to a lower temperature, another class of products would be obtained, as had been pointed out by Dr. Armstrong in a recent discussion. It was as well that engineers should bear that in mind, as they were now witnessing an inauguration of a new series of industries, namely, the partial carbonization of coal in coke ovens, partly for the purpose of getting the products direct, instead of through the gasworks. Those other products might be valuable, but they were not the same as far as the preparation of timber was concerned, for they were lighter and more volatile. He had taken the trouble to get some truck-loads of different coals used ordinarily by the London Gas-companies; he had carbonized them on a large scale at lower temperatures, and had found that he obtained thinner and lighter oils with a specific gravity of from 930 to 1,030, instead of from 1,045 to 1,060, and he had a different class of products altogether.

Dr. C. Meymott Tidy. Dr. C. MEYMOTT TIDY said it was twenty years ago when he commenced working with creosote, and he was bound to admit that since that time his views had undergone considerable changes; but he supposed there was no great harm in that, for the views of engineers, politicians, and even of theologians were constantly shifting. The process of creosoting was of a threefold nature. First, there was the physiological action of rendering the wood a poison, so that animals could not or would not attack it; secondly, there was a chemical action, consisting chiefly in the coagulation of the albumen; and thirdly, there was what he held to be by far the most important action of the three, namely, the simple mechanical action. The process of creosoting was practically a choking up of the pores of the wood so that neither air, moisture, nor life could get inside. He well remembered the late Dr. Letheby drawing up his original specification. No doubt he was

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very strong in his belief of the enormous value of carbolic acid; indeed he regarded it, as the Author had stated, as probably the most important ingredient of the tar. In the last specification which he, Dr. Tidy, had drawn up a year ago, and which was now being employed largely, he had laid down three essentials, and as they practically represented the views which he held on the subject at the present time, he might be allowed to refer to them. The first point of the specification was that the creosote should be completely liquid at a temperature of 100° Fahrenheit, no deposit afterward taking place until the oil registered a temperature of 93°. That point was considered very fully. The temperature at which creosoting was performed was about 120°. It did not appear to him to matter one iota how solid the creosote was (and he was bound to say that from his point of view the more solid it was the better), so long as it was liquid at the temperature at which the creosoting process was done. Seeing that the process was carried out at a temperature of 120°, he thought he was right in specifying that the creosote should be liquid at the temperature of 100°. The next point was (he had left out a specific-gravity clause) that, tested by a certain process, the creosote should yield a total of 8 per cent. of tar-acids. He was aware that in an earlier specification drawn up by Sir Frederick Abel and himself three years ago, they specified 10 per cent., and of course it was only fair to ask him why he had thus degenerated. Having examined a very large number of creosoted timbers that had been prepared for at least a year, he was unable to detect the slightest trace of carbolic acid in them. This fact had also been very prominently and well brought out by Mr. Greville Williams. But although after a short period there was no trace, so far as he could make out, of carbolic acid in the sleeper, yet the wood continued as sound as ever. It was also a fact that the earlier timbers were creosoted with heavy oils containing only a small quantity of carbolic acid, nevertheless these very sleepers laid the foundation of the success of creosoting as a process. Taking those two facts together, it appeared to him that they had hitherto placed an exaggerated value upon the carbolic acid. He did not wish to be misunderstood. He did not say that the carbolic acid evaporated nor that it might not undergo certain chemical changes in the wood; he did not know what took place, and that was not the place to discuss the question. It was on the ground, however, he had mentioned, that he had fixed the quantity of the carbolic acid as low as was consistent with obtaining a genuine creosote. In other words he fixed 8 per

Dr. C. Meymott Tidy.

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Dr. C. Meymott Tidy.

cent., not because he regarded 8 per cent. as necessary for the purpose of creosoting, but because he thought from a large number of analyses of London creosote, that by fixing 8 per cent. he should ensure the obtaining a genuine creosote. In the other part of his specification he admitted that he had completely altered previous specifications, namely, in requiring that the creosote should contain at least 25 per cent. of constituents that did not distil over at a temperature of 600°. He believed that up to that time almost every specification had required that the oil should contain at least 75 per cent. of matters that did distil over at 600°. He entirely agreed with the Author that it was to the heavier oils that the success of the creosoting process was due, and it was therefore by the amount of those oils that did not distil over at a temperature of 600° that the excellence of the creosote to be used for creosoting purposes should be determined. It appeared to him to be highly advisable to get the heaviest creosotes for the work, and to insist upon as great a quantity as possible of the creosote being driven into the wood.

Dr. H. E. Armstrong.

Dr. H. E. Armstrong said that on the whole he concurred in the views expressed by the Author. He thought that creosoting, instead of being an operation of a three-fold character, as Dr. Tidy had stated, was of a one-fold nature. Water had to be excluded, because in excluding water everything was excluded which was likely to be harmful. When water was introduced, other things were introduced with it, especially certain organisms which there could be no doubt played a most important part in effecting the rapid decay of timber. He agreed with Dr. Tidy that mechanically it was of great importance to choke up the pores, but the object was not so much to choke up the pores as to prevent the perpetual moistening of the wood. When wood was moistened, and was subject to frequent variations in pressure, it necessarily became after a time reduced to a very spongy condition mechanically, and its quality was in that way materially affected. If, therefore, the access of moisture could be prevented an important point was gained. The Author had briefly referred to Pasteur's experiments, which perhaps were not so well known as they deserved to be. He supposed that the experiment to which special reference was made was that conducted with saw-dust. Mr. Pasteur had shown that if ordinary moist saw-dust had air passed over it for a few hours there was obvious evidence of decay afforded by the production of carbonic acid. But if precautions were taken to kill all the organisms attached to the saw-dust by heating it, and if it was

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then moistened with water deprived of organisms, and exposed to a current of air carefully deprived of organisms by filtering through cotton-wool, the current of air would pass over it for hours without there being any evidence of the decay of the wood. That was the fundamental experiment upon which the views of chemists with regard to the part played by organisms were based at the present day. With reference to the Author's remark as to the difference between creosote properly so-called and coal-tar oils, he thought there was a little misunderstanding on that point. The Author stated "Creosote, correctly so-called, is the product of the destructive distillation of wood, and coal-tar does not contain any of the true Creosote, which has never been used for timber preserving." That was not quite correct, because true creosote contained a considerable quantity of carbolic acid and cresylic acid, which had been commonly regarded as active constituents of ordinary creosote oil. With reference to what was really the active constituent in creosote oils, the remarks of Dr. Tidy met with his approval to a large extent, but he should be inclined to predict that before many years Dr. Tidy would drop his limit from 8 per cent. to 6 per cent., and perhaps eventually sink it altogether. It was very much to be hoped that that would be the case, because he thought that engineers were using a material for creosoting that ought not to be employed for that purpose, and probably the carbolic acid was practically of very little use. He did not think that the coagulation of the albumenoids to which reference had been made took place to any large extent, or was an essential part of the process. That was, he thought, the only part that could be assigned to the carbolic acid. There could be very little doubt that within a comparatively short time, either by evaporation or by being dissolved out, the carbolic acid disappeared. It was not there in any form, but actually went away. There was no probability that it would be fixed in such a way as to escape attention and detection by the tests employed by Dr. Tidy and Mr. Greville Williams. He was inclined to think that the action was mainly a choking action as described by Dr. Tidy, the access of water to the wood being prevented. It was therefore simply a question of obtaining an oil which would do that in the best possible way, which could be introduced into the wood with the greatest readiness, and would remain in it under ordinary conditions for the greatest length of time; and if, as the Author had said, with the oil which would exercise that action engineers could introduce substances like acridine and other compounds of a poisonous character, so much the better.

Dr. H. E. Armstrong.

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Prof. A. Voelcker. Professor A. VOELCKER remarked that, as had been pointed out by the Author, the antiseptic treatment of timber had almost entirely superseded former methods, and justly so, for on the strength of past experience there could be no question that, when properly carried out, the impregnation of timber with crude creosote was the most efficacious, the least troublesome, the most persistent, and the cheapest process that could be adopted. He gathered from the Paper that the Author was rather inclined to think that chemists had attached too much importance to the presence of carbolic acid in creosote oil. He had pointed out that certain alkaloids in coal-tar possessed antiseptic properties, even in a higher degree than phenol, and had suggested whether it would not be desirable to modify somewhat the specifications issued by the Crown Agents for the Colonies, by the War Office, and other public bodies. Professor Voelcker agreed that the heavy tar-oils were extremely useful, and perhaps more so than the light tar-oils, for preserving timber intended to be used for railway sleepers. He could not go so far as Dr. Tidy, who had suggested (he granted somewhat vaguely) that chemists had attached far too great importance to the presence of carbolic acid in crude creosote. But he would go so far as to say that for preserving well-seasoned old timber, it did not, perhaps, matter so much whether there was a high percentage of carbolic acid in the creosote, as it mattered that there should be present in it a high percentage of the oils which passed over on distillation above 610°, because, as Dr. Tidy had pointed out, the effect of those tar compounds was to close up the pores of the timber, to render it impervious to water, air, and other debasing influences; being at the same time in itself, comparatively speaking, an imperishable substance, like all pitchy products when completely dried. But it should be borne in mind that it was requisite not only to preserve well-seasoned old timber, from which the moisture was expelled almost completely, but that of late years a great deal had been done in preserving telegraph-posts, gate-posts, wooden fencing, hop-poles, and the like, for which sapling-wood, or at any rate young wood, was used. There was a great deal of difference in the chemical constitution of the two kinds of wood. Sapling-wood was more or less filled with sap, and in the liquid which circulated in it there were perishable substances belonging to the class of albumenoids, which acted as ferments, and caused otherwise comparatively imperishable substances to decay. The primary causes of decay of green wood were unquestionably the albumenoid substances; and all the older processes, such as the corrosive sublimate, or kyanizing plan, or the impreg-

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nation with other metallic salts, were based on the principle that by those metallic salts, notably by the bichloride of mercury (corrosive sublimate), the albumenoids were precipitated, and rendered insoluble and incapable of acting as ferments. In green wood also, the cellulose was in a more tender condition than in old wood, where there was a larger proportion of encrusting matter; there was, therefore, a greater reason for preventing the first state of decomposition; and he questioned whether creosote, which was sometimes extremely poor in carbolic acid, was the proper material for preserving wooden structures of the kind he had mentioned. No doubt there was a good deal to be said in extenuation of the qualities of creosote, for the process of preserving wood in open tanks, was sometimes unskilfully—not to say carelessly—conducted; but, making all allowance for the imperfections of the methods for preserving wooden poles in that way, there could be no doubt that sometimes creosote answered remarkably well, and in other instances the same process tended to make the wood more perishable than it would have been had it not been creosoted at all. That seemed to be a contradiction, but according to the evidence of those who had carried on the process with more or less success for fifteen years or longer, the same kind of creosote would answer extremely well for preserving hard timber used for railway sleepers, while for young wood it did not answer the purpose. He had found, from the examination of samples which had been sent to him, that there were great differences in the composition of different creosotes. Not long ago he had received a sample which yielded, on distillation from the boiling point up to 610°, only 39 per cent. of distillate, containing no more than 3 per cent. of carbolic acid; while another sample yielded 14¾ per cent. of a watery liquid with a little light oil, the water being strongly ammoniacal; and it was well known that any ammoniacal water left in the creosote was extremely injurious to the timber. The same sample only yielded 47½ per cent. of distillate, including 4¼ per cent. of crude carbolic acid. In a third sample he found only 5 per cent. of carbolic acid. He ventured to think that creosote containing as little as 5 per cent. of crude carbolic acid was not a good liquid for preserving immature wood, simply because it was not strong enough to precipitate or render ineffective albumenoid substances. Even Dr. Tidy, in the recent modifications of his views, still recommended that the creosoting liquid should contain as much as 8 per cent. of crude carbolic acid. A great deal had been said about the specific gravity of the creosote. He confessed that he did not attach very great importance to specific gravity, but he

Prof. A. Voelcker.

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Prof. A. Voelcker. did attach great importance to the presence of a fair percentage of phenol, or crude carbolic acid, if it was wished to preserve green wood, such as that used for telegraph posts or hop-poles; because it was essential that the first tendency to subsequent decay should be counteracted, and that could not be done without the introduction of a sufficient quantity of carbolic acid. In the case of hard timber the main object was to fill up the pores. There was not so much albumenoid matter present, and the timber would keep fairly well if moisture was excluded; that was effected by heavy tar oil which filled up the pores, and rendered the wood very hard, so that there was not the same necessity for the presence of carbolic acid. He could even understand that if crude creosote contained a very small quantity of carbolic acid, as in the case he had mentioned, and if there should be a large proportion of the more solid constituents of creosote, the pores externally at any rate would be closed up, and the same thing would take place by painting or pitching unseasoned wood; the solid constituents closed up the pores of the outer layers, introducing nothing to render the albumenoids ineffective as a ferment, so that the moisture was kept in, and in that way decay was actually hastened, whereas if free passage were allowed, the wood would be washed out and would keep longer. Engineers knew from experience that green wood, when thoroughly painted or pitched, decayed more rapidly than wood in its natural state. In order that the point might be settled he would suggest that some experiments be tried with creosote containing various proportions of carbolic acid, not with reference to the preservation of railway sleepers, but of younger wood. Strictly comparative experiments should be made with crude creosote, one sample containing 5 per cent., another 10 per cent., and a third 15 per cent., that being the usual range of carbolic acid in commercial creosote. Some well-conducted experiments in open tanks with creosote of various strengths would, he thought, finally settle the question. He could not help thinking that it would be requisite for the proper carrying out of the process that there should be something like 10 per cent. of crude carbolic acid in the creosoting liquid; at any rate, without further information on the subject, he should be disinclined to recommend anybody wishing to preserve hop-poles or telegraph posts to use any liquid containing a less amount than he had mentioned.

Mr. H. K. Bamber. Mr. H. K. Bamber said it appeared to him that the whole secret of the Paper was to be found in the paragraph, "By the light of the evidence now accumulated, it may be advisable to review the

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question as to the relative value of these various bodies contained in the heavy oils as regards the preservation of timber. Some of them are becoming valuable for other purposes. Which of them should the engineer retain for injecting wood?" Carbolic acid, if left in creosote, was worth 2*d.* a gallon, and if taken out from 4*s.* to 40*s.* per gallon, according to the state of purity. The Author's idea appeared to be that nothing should be left in the creosote which it would pay him better to take out; in fact, there should be nothing left that was worth more than the proverbial 2*d.* He did not appear to see the difference in colour between the two pennies and the two sovereigns. The difference in the town-made tar and the country tar did not arise so much from the difference of coal used as from the degree of heat used in making the gas. In London it was desired to obtain a harder coke that would do for engines, and for that purpose a much higher temperature was used, and the most luminous portion of the gas first formed was decomposed on coming into contact with the sides of the red-hot retort, the result being gas charcoal, naphthalene, and a gas of less illuminating power. With regard to Dr. Letheby's specification, that very specification was advocated and recommended by Messrs. Burt and Boulton, but then carbolic acid had not become so valuable when separated. Now the specification recommended was drawn up by Dr. Tidy, and if the Author could get his views adopted there would soon be a good specification to work from. The Author had mentioned some experiments of Dr. Tidy's with naphthalene injected into wood, but he had given no facts or data, merely expressing his own opinion. Again, the experiment was not similar to the exposure of creosoted sleepers, which were not subjected to a temperature of 150° Fahrenheit in a closed vessel. He would give the results of two experiments that he had made in 1882, one with Country oil, condemned by the Author, and one with oil manufactured by Mr. Boulton full of naphthalene. He took a piece of wood (deal), 3 inches by 3 inches by 8 inches, and dried at 230° Fahrenheit, until it lost no more weight, so that there was no water left in it to cause loss. He then kept it in a vessel containing the Author's London creosote, heated to 180° Fahrenheit, having a weight on the wood to keep it under the creosote. It took up 1,020 grains, after being wiped from excess of creosote outside. It was then, on February 7th, 1882, placed on a mantelshelf, where the temperature was never above 70° Fahrenheit, and generally between 40° and 50°. It was repeatedly weighed, and the loss was constant until June 5th, 1882, when it had lost 487 grains, equal to 47·75 per cent. of the creosote put in. Mr. H. K. Bamber.

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Mr. H. K. Bamber. Now, as there was only 10 per cent. of crude tar-acids in the creosote, what was it that made up the 47·75 per cent. loss? Water there was none. The loss arose chiefly from evaporation of the naphthalene. At the same time he treated a similar piece of wood, 3 inches by 3 inches by 6 inches—2 inches shorter—dried at the same temperature, until it ceased to lose weight. It was then immersed in country oil, specific gravity 1,045, and kept under the oil by a weight, but without applying heat. It absorbed 1,788 grains of the creosote, so that the wood, which was a quarter smaller, took up actually, in cold, more than double the quantity that the other piece did of the Author's oil at 180° Fahrenheit. The piece was placed side by side with the other on the mantelshelf, and in four months it had lost 575 grains, or 42·33 per cent. of the oil taken up. But that was not fair to the second piece of wood, for it was so saturated that some of the oil drained out on the mantel-shelf, and of course contributed to the loss of weight, although it was not by evaporation. The oil contained about 20 per cent. crude tar-acids. Those were plain facts, and showed that the Author's contention "that country oils are not good for creosoting timber because of their instability" was contrary to fact. The beautiful white substance, naphthalene, was liable to sudden changes. It might at one moment be a black dirty-looking substance, and, by the application of a moderate heat, it became volatilized and condensed into a lustrous substance. The Author, by Dr. Tidy's experiments, had tried to make out that it was not volatile. Camphor, although it could not be volatilized by heat without decomposition, yet it was well known that a piece of camphor, even when wrapped in paper or any porous material, would soon pass away by evaporation; and it was so with the naphthalene. Many attempts had been made to prepare tar colours, &c. from naphthalene, but as yet without success; it was worth nothing (except in small quantities in the albo-carbon gas-burners) when separated from the creosote; and that was the reason why it was so valuable, according to the Author, in the creosote. But if ever by chemical research naphthalene became as valuable as carbolic acid, it would then become so volatile as to escape from the creosote altogether, and chemists would be asked to reconsider their creosoting specifications. As to the solubility of carbolic acid in water and alkaline solutions, which the Author said was a disadvantage, he maintained that it was an advantage, for it enabled the acid gradually to dissolve in the water and sap, and thus get into the substance of the wood and prevent decay, while the other portion of the creosote remained like beauty, only skin-

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deep. To say that because carbolic acid could not be found in creosoted sleepers after twenty or thirty years, and that therefore it had nothing to do with stopping decay, was absurd. It might as well be said that a few days after a large fire only one or two policemen were found and no fire-engines, and that therefore the policemen put out the fire and not the engines. Carbolic acid was an oxidizable substance, and would protect the wood from oxidation or decay. It instantly prevented decomposition, and destroyed the life of the germs which caused decay, being also poisonous to most insects. Dr. Tidy had mentioned the number of analyses he had made, and how long his experience had lasted. Mr. Bamber might therefore be allowed to state that he had tested samples of creosote for the last twenty-five years, and had practical experience in the process of creosoting. It was his opinion that to creosote timber properly the creosote tank must not be only the "waste tub" for distilling works. It was easy to get good country oil with 18 to 25 per cent. crude tar-acids, yielding no deposit of that volatile substance, naphthalene. He had met with some samples of so-called creosote that contained nearly half their bulk of filth, consisting of charred oil, &c., he presumed the residues from anthracene manufacture, yet when the creosote was rejected every effort was made to induce the belief that it was some of the best creosote. Mr. H. K. Bamber.

Dr. ALBERT J. BERNAYS said that no one could doubt the conclusion that the substances preferred should be germ-excluders as well as germicides, and those contained in the oils which were heavier than water. His contention would be to retain, at least in part, and to the extent of 2 per cent., the carbolic acid as well as the naphthalene and the alkaloids. The arguments in favour of carbolic acid were very strong. Where the creosoted timber was covered up in the ground the solubility in water assisted in diffusing it somewhat in the earth, and thus extended its sphere of action. Nor should that solubility be exaggerated. In a dry soil the loss could only be by heat, and that would also affect other ingredients. It said much for the durability of carbolic acid that, in spite of the employment of heavier types of tar-creosote in early days, it was distinctly present in many cases recorded in the experiments of Mr. Greville Williams. In one specimen wood creosoted thirty years, distilled with water, a distinct reaction of phenol was obtained in a case where most of the oil and all the naphthalene had disappeared. In another, creosoted thirty-two years, the phenol reaction was very distinct. In a third, creosoted twenty-nine years, the phenol reaction was very strong when distilled with Dr. A. J. Bernays.

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Dr. A. J. Bernays. acid, but was also distinctly present in a free state; whereas there was no naphthalene and very little oil. In cases where no free phenol was found, it was discoverable in combination. The power possessed by phenol for coagulating albumen could not be exaggerated. He would not describe his own experiments; but in his hospital work he was very familiar with the high antiseptic power of carbolic acid. The experiments of Mr. Greville Williams with the white and yolk of an egg only showed that the alkaloids of the tar-creosote, weight for weight, were equal to the carbolic acid as germicides, but certainly no more; and that the $\frac{1}{1000}$th part of phenol bore no relation to the amount of albumen present. If all the albumen had been coagulated it would not have putrefied. For Mr. Williams further stated that 1 per cent. of phenol and 1 per cent. of alkaloidals were of equal value. He believed in the coagulation theory by phenol of the albumen of the wood, but unless enough was used it was as with disinfectants. If he had a quantity of hydrogen sulphide in the air of a room, and he only used enough chlorine to unite with one-half of the hydrogen present, where would the disinfection be? It was the worst of disinfectants that generally they could not be used in sufficient quantities. The benefit derivable from them was (as Miss Nightingale had said) that it was necessary to open the window when they were used. It was the same with phenol. If he did not coagulate the albumen, of which there was but little in the wood, he failed. But the phenol had the property and the additional advantage of volatility. It took a long time for even the free phenol to evaporate, so much was it protected and shut up by the oil and naphthalene in the tar-creosote. And he believed that not only was carbolic acid more potent as an antiseptic than any other constituent of the tar-creosote, but that it was present in larger quantities than the alkaloids which, according to Mr. Williams, were equal to it weight for weight.

Mr. W. Foster. Mr. W. Foster regarded the question brought forward by the Author, as to the value of alkaloidal substances, as a very important one. In a Paper which he had recently read before the Institution,[1] he had remarked on the possibility of some of the nitrogen which he was then in search of being in tar in the condition of alkaloidal bodies. The Author had mentioned five or six of those nitrogenous bodies in Table I., and there were probably others. The recent investigations of chemists had shown that pitch itself contained an appreciable amount of nitrogen.

[1] Minutes of Proceedings Inst. C.E., vol. lxxvii., p. 162.

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Mr. W. Foster.

Acridine, of which an example had been given in the Table, contained the lowest percentage of nitrogen, and had the highest boiling-point. Having regard to the pitch, it was possible that there were other nitrogenous bodies which had a still higher boiling-point, and a lower percentage of nitrogen than in the case of acridine. The quantity of those alkaloidal substances in the tar was very small. There was no information as to their relative proportions; and as the percentage of nitrogen varied from 17·7 to 7·8, it would not be wise to specify how much of those bodies was present in the tar. He thought he might say that there was not more than from 3 to 4 per cent. If, therefore, they had any value in the preservation of wood, their effect must be very powerful. He was inclined to look at the question of the preservation of wood by the aid of some facts which were a little outside the subject. He might be pardoned for referring to the corrosion of iron. Iron could remain permanent in dry oxygen, in pure water, or in pure carbonic acid gas; in any two of those it remained permanent; it was only by the conjoint influence of the three that corrosion was effected. Pitch, he believed, was the best preservative of iron that was to be had, and if applied to a clean surface free from oxide (rust), it was impossible to say when the surface of pitch would fail to protect the iron. He was of course speaking of the continuity of surface being preserved. Pitch was a substance of a most permanent character, being almost destitute of any chemical attributes; if, therefore, the cellular structure of the wood could be thoroughly permeated by it, as long as the continuity was perfect it would be preserved. Of course, that could never be fully realized in practice. In the case of green wood, the question arose as to the coagulation of albuminous matter. No need to go far afield to get plenty of instances showing that if water and impure air could be kept out, the preservation would be prolonged. The Author had referred to the experiments of Pettigrew; but the inference he had drawn was not the only one. If albuminous matter was dried, it could be kept as a horny substance for an indefinite length of time. A piece of glue could be preserved intact in the same way. If white of egg or glue were moistened and exposed for a certain time, it putrefied. The inferences deducible from Pettigrew's experiments could, he thought, be traced to the removal of water from the muscle (the heart), which had been the subject of the experiments. The whole thing might be summed up in the grave-digger's reply to Hamlet, "Water is a sore destroyer of the dead body."

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Mr. W. Carruthers.

Mr. W. CARRUTHERS thought that the botanical aspect of the question should be at the basis of the inquiry; for without a proper appreciation of the circumstances under which vegetable tissues were destroyed, it was impossible rightly to appreciate the means by which that destruction could be prevented. While he agreed with much that had been said, he felt bound to differ from a great deal that he had heard. He acknowledged the great importance of pitch for preserving the external surface of wood. But wood decayed not only from chemical agents, air and water; but much more from the action of parasites. He could easily see that if a body was entirely protected externally by pitch, it would be preserved from chemical changes, but not from the more injurious and dangerous attacks of fungal parasites. They were developed from spores, and the attack might be made through a flaw or crack in the wood. When the wood was exposed to the desiccation of the air, flaws continually appeared, and wherever a spore could get access, there would begin development of the mycelium or root of the fungus which penetrated the wood wherever nutritious materials were supplied through its whole course: so that unless the wood was preserved by some substance which would prevent the life of fungi, its destruction was certain. He exhibited a specimen of wood the date of the creosoting of which was not known, but it had been used in a hurdle for at least ten years. The lower creosoted portion, embedded in the earth, did not show the slightest injury; but the upper part, exposed to the air, and cracked, had been attacked from the outside by minute vegetation. Some of the spores had obtained access to the interior, which had not been antiseptically preserved, the fungi had enormously developed, and the interior had been destroyed by them. The same thing had occurred in the case of two specimens of telegraph poles. The exterior of the specimen which he exhibited had been fairly preserved, but the interior had been destroyed. It was remarkable that the interior was coloured by the injection of what he supposed he must call creosote; but it had not been sufficient to serve as an antiseptic, as it had permitted the free growth of fungi, which ramified through the base of the pole and completely destroyed the cellulose or lignine, leaving it a fragile skeleton. It appeared to him that what was needed was a sufficient impregnation of the wood with creosote, and with that element in it which was destructive to vegetable life. He did not know from experiments what that element was, but he did know that there was an element in crude creosote that was extremely destructive to vegetable life, viz., carbolic acid. Not,

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however, in all strengths, for Koch a distinguished German mycologist, had found that certain liquids, with 5 per cent. of carbolic acid, would support fungi; so that the presence of a small percentage was not destructive to vegetable life. That was extremely important in relation to the observations of Professor Voelcker. Another specimen from a telegraph-pole had been completely destroyed by a fungus (*Reticularia*). There was on one side a yellowish dust, consisting entirely of the spores of the plant. But in a specimen from a hurdle, which had been in use since 1861, when it was creosoted, the exterior, although it had no coating of tar, still exhibited the minutest marks of the tools employed upon it, and the interior, which was completely saturated with a brown substance, was as good and fresh as if it had been creosoted yesterday, without a particle of fungus. There was a little greenish vegetation on the outside, but it was epiphytic, and not injurious to the wood; there was no fungal vegetation whatever. The wood had been enormously increased in weight, and he had ascertained microscopically that there was no deposit in the interior of the cells. The whole of the lignine and of the secondary deposits had been coloured by that material, so that the tissue had been completely altered. It appeared to him that there had been a new combination through the injected material, producing an antiseptic condition of the wood which was fatal to the fungi. There was a little free carbolic acid crystallizing in the interior of the cells, but it did not seem to him that that was the explanation of it. He should be glad if those who were conversant with the chemical aspect of the subject would inquire into the real nature of the change which had produced the discoloured and altered condition of the lignine. In his opinion nothing had been introduced for preserving timber that could compare with the creosote used in the specimen he had exhibited, which had been exposed to the air nearly twenty years, and yet the ragged edges of the chips on the outside had not even been touched by atmospheric or other destructive agents. Mr. W. Carruthers.

Mr. Henry Maudslay observed that in the case of Old London Bridge the decay of the timber piles of the piers varied according as they were constantly under water, or exposed to water, air, and sun; or exposed especially to salt water or to fresh water on the rise and fall of the tide. There were many combinations of circumstances that tended practically to destroy timber, and it was therefore most desirable to ascertain the exact position that would be occupied by a solid pile driven into the earth to support a structure—whether it was to be exposed to the constant action of water Mr. H. Maudslay.

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Mr. H. Maudslay. below in the earth, or to a change in the rise and fall of the tide, or to the influence of moisture gradually attacking it above the highest springtide level. On the Arran and Snowdon mountains he had been lately excavating soil in order to form a reservoir, and had come across some of the largest roots of red pine timber that he had seen in that locality. There were no trees on the mountains at the present time, and it must have taken many years for the timber to have grown at that elevation—1,200 to 1,500 feet above the level of the sea. The timber was of a magnificent character; these roots had been submerged perhaps centuries. The roots had been found *in situ* covered with a layer of disintegrated earth saturated with water from the copper mines. They had been preserved in that way by nature, but now that they were being exposed to the air they were in some cases beginning to crumble away. The props and supports in old workings of copper mines were preserved, and would burn with great difficulty. Since the "Royal George" had sunk in 1782, all the timber had become saturated with sea-water, which was so destructive to the cast-iron cannon, that they were made as soft as plumbago; but salt water had a great effect upon the preservation of the oak wood, making it quite green. The timber was so hardened that all the pores seemed to have been filled with some material that was suitable to its preservation. It still retained that quality, as shown in the case of a billiard table made for her Majesty, and by another now in his late father's house at Norwood. This table had been made by Thurston in 1860 from the wreck which was raised in 1841. With regard to the decay of iron, he might be permitted to mention that Queen Anne's statue at St. Paul's cathedral was one of the finest of London specimens of decay of iron that engineers could examine. It consisted of cast iron, wrought iron, lead, and stone, all of which were mouldering away by the action of nature, the character of the air, and the water. The whole of the ironwork was a magnificent specimen of age and deterioration. If chemists would examine the question as to the effects produced upon timber subjected to the continual action of water and its components, or to the rise and fall of the tide, whether salt or fresh, or only to the effects of a certain amount of moisture, as in the case of railway sleepers afterwards dried by the action of the sun, the practical results of their investigations would be of great value.

Mr. E. A. Cowper. Mr. E. A. Cowper said he understood that an examination of the old pieces of timber successfully creosoted that had been exhibited showed they were not at present protected by tar acids,

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and if they had had any in them in the first instance it had long ago evaporated. The unsuccessful telegraph-pole exhibited by Mr. Carruthers, from which a specimen had been taken, had evidently not been put into a creosoting cylinder, for it had a mere slight covering of creosote outside. Hop-poles were often put into an iron pan with a fire under it and made hot, and there could be no doubt that steam came out from the water evaporating, and the very action of which the Author had spoken took place to a slight extent. The piece of wood that was cut to a taper had a little creosote in its end, but on its sides the creosote did not go in $\frac{1}{16}$ of an inch, it was merely paint on the outside; where the mortise-holes had been put through the post the spores had entered and attacked the inside. The effect of a spore getting into a piece of timber that had been preserved only on the outside surface was no argument against the preservation of timber by creosote. The piece from the Victoria Dock fence, which had been well creosoted, had been preserved, and was as sound as it was twenty-nine years ago when it was put down. The creosote had gone to the middle of the wood and protected it. The other specimen had not been preserved, and therefore it was rotten. A very extensive series of experiments had been carried out by Mr. Charles Coisne, and they were of a very instructive character. Samples of creosote had been taken from England, Scotland, Belgium, and France, showing 15, 15, 8, and 7 per cent. of tar acids, and there was a fifth specimen of heavy oil without any tar acid. Other mixtures were made by putting in an extra quantity of tar acids, except in the case of the one kept without acid; and the result showed that where the heavy oil was used the wood was preserved in the best manner, whilst those samples of wood preserved with creosote, having an extra dose of acid, were not so well preserved, and that which was unpreserved was entirely rotten. He had gone to Silvertown to examine the apparatus to which reference had been made. There were a number of pipes in the bottom of the creosote cylinder with superheated steam in them. When the timber had been put into the cylinder and warm creosote run in upon it, the temperature was gradually got up, and the water was as effectually driven out of the wood by evaporation as would be the case if water was put in a boiler with a fire under it and kept without any fresh supply of water. A temperature of 220° or 230° would evaporate every particle of moisture out of the wood, more especially when a vacuum was put on. He might mention that the vacuum should not be turned on suddenly, otherwise the creosote, steam, and

Mr. E. A. Cowper.

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Mr. E. A. Cowper. water would all boil over. Water was deposited in a vessel in connection with the condensing pipe together with some light hydro-carbons. The creosote supplied to the creosoting-vessel being heavy oil, would not commence to boil until about 392°. London creosotes contained about 4 to 7 per cent. of tar acids. He had himself tried some experiments in coagulating and precipitating albumen, and he found that considerably less than 2 per cent. of carbolic acid in the creosote would precipitate the largest amount of albumen found in wood; so that there was amply sufficient carbolic acid in the London creosote for that purpose. Not only was the albumen coagulated by the 2 per cent. of carbolic acid, but by the mere fact of its being boiled. If an egg was boiled a short time the white would set, and in an hour or two it would be very hard. After the vacuum had been on for a sufficient time, and the whole of the water and moisture withdrawn from the timber, the cock was turned and the pressure put on with pumps up to 120 lbs. to the square inch. Not only did the pumps put on the pressure and force the creosote into the wood, but directly the temperature was lowered a little, steam condensed, and there was a vacuum in every pore of the wood. The whole of the wood was made a condenser; in every pore that had previously contained water there was a vacuum so that the creosote went in, and besides that, there was the pressure of 120 lbs. to the square inch. At the works he saw a whole range of tanks following one after the other. He thought the method was a very practical and mechanical one. There could be no doubt about the creosote thoroughly entering the timber. He thought the thanks of the members were due to the Author for the admirable way in which he had developed the subject. The only thing wanted was a sort of skeleton specification for their guidance in the future.

Mr. W. H. Preece. Mr. W. H. Preece said that as the behaviour of certain of Her Majesty's telegraph-posts had been called in question he ought to say something in their behalf. For the last thirty years he had devoted all the attention and skill that he could command to the inquiry as to the best modes of preserving timber. In the telegraphic service of the country many millions of poles had been preserved in various ways, and one of the methods—that explained by the Author—had proved to be the survival of the fittest. A great deal had been said as to the various causes of decay. Reference had been made to chemical and physiological causes, but there was a third cause, which might be called mechanical, of the decay existing at the "wind and water" line, or the ground-line,

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where the timber was exposed to incessant changes of moisture and temperature. A careful microscopic examination showed that the process of decay was a purely mechanical one, that the wood disintegrated by a process of bursting. The fibres appeared to be minute boilers, and the change of temperature produced evaporation, minute explosions, and rapid deterioration. It was a simple thing to meet the chemical cause by the insertion of salts of various kinds, and it was possible to meet the physiological cause by antiseptic treatment; but the mechanical cause could only be obviated by coating the fibres of the wood with water-proof material, and filling them with a thick viscous mass like creosote in its best form. In 1844 the first line of telegraph was constructed between London, Southampton, and Gosport, and the posts were made of best Memel timber preserved by the Burnettizing process, simply impregnating the wood with zinc chloride. In 1857 he made a personal observation of a great part of the line in different grounds, and found that in sand about 40 per cent. of the posts had gone, in clay about 33 per cent., and in chalk about 28 per cent. In 1860 he found that the proportion was much greater, and in 1871 they had all failed, so that they had to be removed. The Burnettizing process materially added to the life of the pole without rendering it indestructible. Kyanizing was tried to a small extent, but the poisonous character of the salt deterred him from carrying it farther. The favourite process about twenty years ago was that of Boucherizing. The authorities had purchased whole forests, and in the middle of them established the Boucherizing process, by which they had succeeded in lengthening the life of timber considerably. While the life of an average telegraph-pole unprepared was about seven years, the life of a Boucherized pole was about fifteen years. In 1848 a line of poles was erected from Fareham to Portsmouth, a distance of about 20 miles, and all the poles, three hundred and eighteen in number, were creosoted by Mr. Bethell. In 1861 he examined them all *in situ*, and only two showed the slightest trace of decay, and they had begun to decay at the top. In 1874 he had them again examined, and every pole was sound. Last year, owing to the requirements of the service and the necessity of increasing the number of wires, the line of poles had to be taken down, and although they had been put up in 1848, they were as sound as when they were first erected. About the year 1861 the question of the proper mode of preserving timber was one of great consequence. The authorities were not satisfied as to which was the best, Boucherizing or creosoting, and consequently, on the Yeovil and Exeter line of the London and South

Mr. W. H. Preece.

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Mr. W. H. Preece. Western Railway Company the poles were put up alternately: first, a plain pole; next, a Boucherized pole; and next a creosoted pole, the line extending about 40 miles. In 1870 he had them carefully examined, and it was found that of the plain poles that had been up 10 years not one existed, all having decayed; while of the Boucherized poles 30 per cent. had gone, and of the creosoted poles not one had decayed. The result was that the Government had decided for years past to creosote all their poles. He did not remember the exact specification that was used. At present the millions of poles existing in the country were all creosoted. It was true that some of them had failed; but, as Mr. Carruthers had pointed out, there was creosote and creosote. There were unreliable firms, and others in whom confidence could be placed; there were inspectors who could be trusted and others who could not. There were poles about the country supposed to be creosoted that were rotten; and it had been found that those particular poles had not been inspected, and that they had been hastily and improperly impregnated. He could state, as the result of thirty years' experience, that he had never seen a case of a properly creosoted pole showing the slightest sign of decay.

*** The reply of Mr. Boulton upon the Discussion and Correspondence is given at the end of the Correspondence, p. 190.

Correspondence.

Mr. A. Bouissou. Mr. A. Bouissou, of the Western Railways of France, stated that in 1859, on the line from Rouen to Dieppe, sleepers creosoted by the Bethell process had been adopted for the first time. These sleepers were of beech. They had been creosoted in England in the works of the Author's firm, and when an examination of them was made twenty years later, on the occasion of the Paris Exhibition of 1878, it was shown that not a single one of them bore the slightest trace of decay. Since 1864, the railway company of which he was engineer of the permanent way, had adopted creosoting for their sleepers, and from that date they had applied it to about five million sleepers, of which at least three million and a half were of beech wood. In these latter, as in the trial sleepers of 1859, no sign of decay had as yet been distinguished, and the lasting powers of the sleepers seemed only to be limited by the wear and tear to which the materials were exposed. Beech wood placed in the ground, without having been prepared, completely decayed at the end of two or three years, which rendered impossible

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the use of that wood unprepared in the form of sleepers. Also sulphating, employed for a long time for beech sleepers, not having given the good results expected, had been abandoned by all the French railway companies. Mr. A. Bouissou.

The employment of creosote for the preservation of sleepers had given every satisfaction, and its use had only been limited at certain periods by the difficulty sometimes experienced in procuring a sufficient quantity of creosote. As regarded the quality of the creosote, he simply required that it should contain 5 per cent. of carbolic acid.

Mr. W. A. Brown remarked that a preserving process, of which much had been said and a great deal expected by engineers a few years ago, had been referred to in the latter part of that portion of the Paper devoted to "Apparatus for Timber Preserving." This process was Mr. Blythe's system of "Thermo-carbolisation," which had been carried out by Messrs. Conner and Co. at their works at Millwall, when a large number of sleepers had been prepared for some of our railways, together with telegraph poles for them and for the Post-office. It became his duty, about four years ago, to inquire into the subject, and he made an investigation into the different stages of the process at Messrs. Conner and Co.'s works, which led him to the following conclusions:— Mr. W. A. Brown.

1st, that the strength of the wood was impaired through some of the cellulose and its incrusting materials being carried off in the form of pyroligneous acid by the superheated steam.

2nd, that the peculiar "Creosote mixture" used as part of the process, contained so large a proportion of water that it was not at all likely to act as a preservative of the sleepers to which it was applied.

It would be interesting to hear now how the sleepers and poles thus prepared had actually lasted in this country. In Austria the experience of Mr. Seidl, and in France that of the Author, as recorded in the Paper, appeared to confirm the conclusions at which Mr. Brown arrived in the course of his investigations; but so far as he was aware, there were no published results as to the process in England.

Mr. John Cleminson observed that the question of preparing timber against decay was occupying more attention now than formerly. It was therefore to be regretted that the Author had not referred in detail to many good processes with the above object in view, namely, that of Sir John MacNeill, Gardner, Beer, Blythe, and others. The Author's remarks in reference to carbolic acid as an antiseptic would lead to the idea that it was necessary the acid should remain when injected; such was not the case, nor was it necessary. The mere fact of its presence (carbolic acid being the most powerful Mr. John Cleminson.

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Mr. John Cleminson. antiseptic known), with super-heated steam, was all that was required to produce coagulation of the albumen, and so to render preservation practically complete. With the old process of creosoting, only the exterior surface was preserved, the interior if unsound decayed uninterruptedly. All depended upon the selection of the timber. No amount of creosote would avail to save its destruction ultimately, if the interior was not sound. Where sleepers were adzed, the greater part and in many instances the whole of the part, penetrated by the creosote was cut away, thus leaving the interior open to destruction from damp and other causes. The same disadvantage was experienced in the case of piles, when the ends were pointed for receiving shoes after creosoting. With carbolic acid once in contact with the albumen, and in the event of any interior unsoundness, the coagulation arrested decay, and prevented it from spreading, by entirely enclosing the defective part or parts. Combined when necessary with an outer application of creosote, thorough soundness and preservation internally and externally were thus secured. Blythe's process was a double process. The object, preservation internally and externally, in the case of sleepers and piles, was most effectually obtained by carbolizing the interior, and creosoting the exterior. A result had been obtained that had placed this process foremost with French engineers for several years, and it was now largely used by them. In England where used it had met with much favour. The Author of the Paper was employing this process in France.

Mr. R. Cowper. Mr. Richard Cowper remarked that the value of creosote for preserving timber depended partly on the mechanical effect which it had in excluding from the pores of the wood air and water, and the germs of destruction which they contained, and partly on the power possessed by certain of its constituents of destroying those germs. For the purposes of germ-exclusion, it was generally admitted that the heavier portions of the creosote, from the less degree of solubility and volatility which they possessed, and their property of solidifying at ordinary temperatures, were the more efficacious. As regarded the germ destroyers, the phenols and the alkaloids alone need be considered. Phenols, namely carbolic, cresylic, and other acid bodies occurring in creosote, had long been known to possess remarkable antiseptic properties, but they were easily soluble in water, and comparatively volatile. Much stress had been laid upon their power of coagulating albumen, but it had been shown that no stable chemical compound was formed, and that the albumen thus coagulated might be freed from the phenol by washing with water, when it would decay. It had

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Mr. R. Cowper.

been shown by the experiments of Coisne, Greville Williams, and the Author of the Paper, on pieces of old creosoted timber, that in many well-preserved specimens no phenol can be detected by the ordinary test, whilst in most cases they had found naphthalene, and in all cases oils of the heaviest character in considerable quantity. It had been shown by Mr. Greville Williams that all the old timbers examined by him contained a considerable amount of alkaloids, and his experiments proved not only that these alkaloids were powerful germicides, but that they were more powerful than phenol. They were at the same time much less soluble and volatile. Evidently if creosote containing a high percentage of phenol were required, it could not contain so high a percentage of the heavier constituents, which were those possessing the greatest value as germ-excluders. At the same time, some of the alkaloids which had been shown to be of more value than phenol as germicides would be removed.

Mr. R. B. Grantham.

Mr. R. B. Grantham submitted the following information respecting the duration of timber on the Great Western railway system, which had been supplied to him by Mr. W. L. Owen:—

	Years.
Uncreosoted yellow pine	12
Creosoted yellow pine in bridges, viaducts, or in permanent way	Bridges, &c., 20; Permanent way, 30
Timber prepared in any other way	12 to 15
Sleepers creosoted (Baltic)	8 „ 10
Sleepers not treated, but used clean	5
Sleepers kyanized	6 or 7

Name of Railway.	Date of Opening.	Estimated Percentage of the original Timber now in Line.	Remarks.
Uxbridge Branch . .	1856 Sept. 8	50	
Henley „ . .	1857 June	80	
Witham to Strepton . .	1858 Nov. 9	..	
Brentford Branch (narrow gauge added in 1861. ? clean timber) . .	1860 May 18	80	In two lines, narrow-gauge, creosoted. No clean timber in the branch now.
Hungerford to Devizes .	1862 Nov. 11	50	
Thame to Kennington Junction	1863 Oct. 21	80	
Wycombe to Thame (a great deal of Baltic timber was permitted to be used between Risboro' and Oxford. What result?)	1862 Aug. 1 .	80	

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Mr. R. B. Grantham.

Name of Railway.	Date of Opening.	Estimated Percentage of the original Timber now in Line.	Remarks.
Marlborough Branch . .	1862 April 14	50	
Oxford to Reading . .	1856 Dec.	Nil	Reading to Didcot.
(Narrow gauge? Common rail, just new; old common rail moved for narrow gauge) . . .	..	15	Didcot to Oxford, 1856, narrow-gauge.
Paddington to Reading. (A good deal of clean timber was used in the narrow gauge) . . .	1861 Aug.	Nil	Paddington to Slough. All the clean timber was taken out in 1883.
		75	Slough to Reading. Creosoted timber. All clean timber taken out.
Reading to Basingstoke .	1848 Nov. 1	25	Not on pine packing.
Southcote to Hungerford .	1847 Dec. 21	70	Pine packing.
Didcot to Oxford . . .	1856 June 12	Nil	
Didcot Loop	"	"	
Weymouth and Portland Railway	1865 Oct. 16	"	
Thingley to Frome . .	1848 Sept. 5 1850 Oct. 7	75 45	Thingley to Holt. Holt to Frome.
Westbury to Salisbury .	1851 Sept. 9 1856 June 30	70	
Frome to Dorchester Junction	1857 Jan. 20	20	
Devizes to Holt . . .	1857 July 1	95	

Mr. W. Langdon.

Mr. W. Langdon remarked that in 1874 a Paper by him upon the subject had been read before the Society of Telegraph Engineers, in which he warmly advocated the employment of creosote in preference to any other preservative for timber, and he had since seen no reason to alter the views expressed on that occasion. Of late years, however, the appearance of the timber so treated had suggested the belief that the oils now employed did not contain that amount of tar or other heavy compounds which was apparently possessed by the creosote supplied in the earlier days. His attention in the application of creosote to timber had been more in the direction of telegraph-poles than otherwise, which class of timber was much more exposed to the weather than were railway sleepers, and which might in consequence be accepted as affording a more complete test of the value of the oil than did railway sleepers. These to a great extent were buried in the soil, and had but one side exposed to the influence of the atmosphere.

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Of late years numbers of the poles had presented anything but the appearance of a well-creosoted pole. The surface had become partially or wholly bleached, and almost white. This generally occurred on that portion of the pole subject to the sun's rays; but it was also equally marked upon that side of the pole exposed to prevailing winds and wet weather. It would therefore seem as if the bleaching was the result both of the influence of the sun and of the weather; in fact that the creosote disappeared from the surface of the pole under the influence of the sun and of wet. If telegraph poles creosoted many years back were examined, as a rule the surface of those poles would be found covered with a pitchy compound, and that mainly on the side of the pole exposed to the sun. There was no washing out from the weather. This he thought was easy of explanation. The warm atmosphere would always exercise an extractive influence upon any oil injected into wood or other like substance; its tendency would be to bring it to the surface, where the lighter portions would be evaporated, and the heavier portions congealed. Creosote no doubt was a strong antiseptic, but where timber when felled was decayed, it could not give fresh life to the decayed portion. Timber, if properly seasoned, would last many years if not exposed to the vicissitudes of wind and weather, as in the instance of many articles of furniture made from the very same wood from which telegraph poles and railway sleepers were obtained, and which seemingly never decayed indoors. It was here that the creosote process enabled an equally long life to be obtained for it when employed out of doors, and he imagined that the heavier oils played a much higher part in procuring this immunity from decay than the creosote oil, inasmuch as it was to these heavier oils that the exclusion of moisture from the timber was due. A telegraph pole, or a railway sleeper, free from disease, if properly seasoned, and encased in such a manner as to prevent moisture getting into its fibre, was practically indestructible from rot or decay. The coating given to it by the injection of these heavier oils into the fibre to a depth of from 1 inch to 2 inches afforded the timber this coating, excluded moisture, and thereby secured its duration. Mr. W. Langdon.

Mr. C. De Laune Faunce De Laune remarked that the Author had attempted to prove that only a very small quantity of carbolic acid was necessary in creosote for the preservation of wood. He approached the subject with diffidence, as he lay claim to no scientific knowledge, merely discussing it from the purely practical side; and because he had been instrumental in extending the use of creosote Mr. C. De Laune.

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Mr. C. De Laune. among landowners and farmers. The Author referred to his having used creosote too hot, and thereby having damaged the wood, much in the same way as if he had taken a warm bath too hot. He certainly stated to the Author that he had used a material called creosote which contained a very small percentage of carbolic acid, and that the wood had failed to be satisfactorily impregnated with it in an open tank, even when submitted to a great heat; but he scarcely anticipated that he would infer that it was his general custom to use extreme heat, as he only wished it to be understood that even under such conditions the creosote did not perfectly penetrate into the wood. The process of injection, in the case of telegraph poles, might preserve them to an indefinite period, but such a course was frequently impracticable to the former, and in the case of hop-poles impossible; wherefore an open tank was indispensable. For the last twenty years he had used creosoted wood, and the process had always been performed in an open tank. The wood was first cut to the required shape, and then immersed in the creosote which had previously been liquefied and warmed by a furnace built underneath the tank. No thermometer had ever been used to regulate the heat, and the only precaution taken was to prevent the creosote from boiling over, though it was sufficiently heated to make a few bubbles appear on the surface. Wood of all kinds had been used, and no difficulty in applying the creosote was at first experienced, but he believed that the creosote had gradually been becoming worse and worse, and so he submitted it to Dr. Voelcker for analysis, and got the following reply: "Your creosote has a specific gravity of 1·103, and on being subjected to distillation yields only 61 per cent. of volatile oils, of which 4 per cent. are carbolic acid. My experience in creosoting timber, small as it is when compared with that of public companies, is large for a private individual, as I have at this time 46½ miles of fences where creosoted wood is used; and whereas the system, when employed some years ago, was satisfactory, the present results are as much the contrary. The pieces of creosoted wood exhibited by Mr. Carruthers were creosoted by me in 1866, and, as was pointed out by him, are perfect in their preservation. Unfortunately I have no analysis of the creosote then used, for such an analysis would prove that a material of the same constituents would be suitable for preserving wood in an open tank." It was obvious, therefore, that a creosote was formerly used that could and did preserve inferior wood in an open tank perfectly, and which could be used so easily that no particular precautions as to the dryness of the

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wood were necessary, and it was in the hopes of ascertaining the component parts of the creosote which he once used with such admirable results that he ventured on these remarks; for the creosote that he formerly used for preserving wood was as valuable as that which he was now using was useless and worthless, and all he asked of manufacturers was to give him material like that which he had before. Mr. C. De Laune.

Mr. W. LAWFORD wished to inquire how it was that, in the face of such undoubted proofs of the value of the creosoting process, some of the large railway companies, and notably the Midland, had given up creosoting their sleepers? He considered it the duty of every one who used timber largely to adopt either this or some other antiseptic treatment, since large encroachments were annually made upon the timber-growing districts of the world, without an adequate supply of timber-producing trees being planted for the use of posterity. Mr. W. Lawford.

Mr. C. LOWE, in reference to the constituents of the creosotes employed for "pickling" or preserving timber, was disposed to attribute to the tar-acids only a very small amount of the effective results obtained by the application of the creosote, for the following reasons:— Mr. C. Lowe.

1. Carbolic and cresylic acids were both completely volatile even at an average summer temperature in England, and in hot climates could not long remain present (except as traces) in any timber to which they had been applied.

2. Both these acids were readily soluble in water, and would consequently be rapidly removed from the timber in case the latter, previously saturated with them, was subjected to the action of water in motion. He regarded the action of coal-tar creosote in preserving timber as presenting a two-fold character; first, a mechanical action, by which the wood was rendered waterproof from the filling up of the cellular tissue with matter insoluble in water; second, a chemical or antiseptic action, due chiefly to the presence of the tar acids. These tar acids were roughly divisible into the readily volatile acids soluble in water (carbolic and cresylic), and the heavy, almost non-volatile, acids insoluble in water. The latter class had not been thoroughly studied, but it was known to be powerfully antiseptic, and anti-parasitic. He therefore considered the creosote best adapted for the "pickling" of timber to be a creosote containing sufficient solid hydrocarbon, such as naphthalene, to be solid at a temperature slightly above the average climatic or other temperature to which the timber was to be ultimately exposed; at the same time, to prevent the attacks of parasitic insects, &c., the heavy tar-acids should be present. No

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Mr. C. Lowe. reliance should be placed on carbolic and cresylic acids for pickling timber, seeing they were so readily removed by the action of water and climatic heat. It was well known that their albuminous combinations were readily broken up by simple washing with water; as germicides and antiseptics, when retained *in situ*, these acids were invaluable for surgical use and disinfection, and to these purposes they should be relegated.

Mr. T. E. M. Marsh. Mr. T. E. M. Marsh, who had exhibited during the meeting specimens of timber used by the late Mr. Brunel in 1839, observed that these were fair samples of the bulk of the timber of the ribs of the skew bridge over the River Avon, at the Bath station on the Great Western Railway. The timber was cut from Memel balk, and was kyanized. It was quite sound after forty years' service. The kyanizing process had been employed extensively by the late Mr. Brunel in the early works of the Great Western Railway. The permanent-way timbers were thus prepared, and gave excellent results as to preservation from decay, as was shown by specimens cut from various parts of the line, between London and Bristol, after having been laid from fifteen to twenty years. Mr. Marsh had gained much experience in the preparation and uses of creosoted timber, both while acting for Mr. Brunel, and subsequently up to the present time. In the early days of the process, the tar from which creosote was prepared was not subjected to the extraction of so many chemical ingredients as was now the case, and the naphthalene, or salt precipitated was comparatively small, and considered of little value. No difficulty was then experienced in getting a good admixture of light and heavy oil in a fluid state, of satisfactory colour, consistency, and taste, and complying with the rough and ready tests adopted. Mr. Brunel adopted the process extensively from its early introduction by Mr. Bethell, in bridges and permanent way, and much of those timbers and structures remained in use at the present day. It was, however, soon discovered that it was of great importance the timber should be well seasoned and dry, and that it was worse than useless to creosote unseasoned, damp, or wet timber. Some alarming cases of internal decay had been discovered, attributable to these causes. Of late years, on account of the greater demands on the timber merchants, and for other reasons, the preparation of creosoted timber had not always had such careful consideration. The processes were often carried on, not only not under cover, but water in variable quantities was generally found in the tanks from which the oil was pumped into the pressure-cylinders, and solid salts and a mixture of mud and the residuum and drainage of objectionable matter from the timber

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of preceding charges, accumulated in the tanks and returned again, to the detriment of subsequent charges. It not unfrequently happened that timber coming from the pressure-cylinders might be found with some portions presenting no trace whatever of creosote even on the surface, but showing only signs of the contact of dirty water, when the quantity of creosote injected was supposed to have been 50 gallons to the load. Such facts, Mr. Marsh asserted, were sufficient to account for many reported failures, without reference to the chemical questions as to the relative values of the constituent parts of the oil. Mr. Marsh's instructions to his inspectors for the preparation and pickling of timber, where thorough efficiency was desired, were based on his own personal observations, and were as follows:— Mr. T. E. M. Marsh.

"The state of the tanks from which the creosote is being drawn while the pressure progresses, and before any creosoting is done, must be examined, and if found to contain salty or muddy sediment at the bottom, or water at the top, or the nature of the creosote otherwise bad, its use must be protested against. Samples must be taken by a tube dipped to test the liquid at various depths, particularly the upper and lower portions of about 12 inches of the top, and the same at the bottom. This must be strictly attended to. No steam shall be let into the creosote anywhere. The numerous pipes used for heating, and sometimes hoses and joints, may give the means of mixing in steam during the process, and hence the condensed water, which must not be permitted under any circumstances. Sometimes the appearance of the timber after creosoting will show that water has been in contact with it. The thorough good creosoting must also be checked by a chisel at the sound hearty parts of the timber, and the penetration checked by weighing trial sticks with each charge (these should not be open sappy timbers, and they should be the least dry rather than those to favour absorption more than the bulk in the same charge). A good percentage, over 50 gallons to the load, must be injected so as to allow for outside drainage when drawn out of the cylinder. In weighing, 50 gallons may be reckoned as 550 lbs. If the timber be not quite satisfactory and perfectly dry, and immediate delivery is urgently wanted, then a considerable extra quantity must be injected, as much as 10 per cent., or further drying, and under cover, must be insisted upon, but in no case must positively wet or damp timber be allowed to go into the pressure-cylinders."

Mr. BENJAMIN NICKELS observed that he was much gratified in noting that the Author had drawn special attention to the com- Mr. B. Nickels.

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Mr. B. Nickels. pound acridine, pointing out at the same time its high antiseptic value as a constituent of creosoting materials. It would appear that his impressions had been based on certain marked properties exhibited by this peculiar substance, notably its intense pungency, acridity, and high antiseptic value, also its immunity from loss by evaporation and the solvent action of water. As little beyond a mere reference to the compound had been made, it might be of interest to state what had been done in other directions, and so far as it might corroborate the views advanced by its Author. In the year 1882 he was induced to take out a patent for a composition to be used as an insecticide, and for the coating of ships' bottoms and other submerged surfaces, and in which acridine played an important part. He had during a previous experience met with many opportunities of observing the painfully irritating action of the heavier tar oils, arising from handling during the treatment and purification of anthracene, due to the presence of acridine, and as an outcome of the observation it had occurred to him that this substance should constitute an effective "antifoul," inasmuch as it would be almost impossible for animal life to remain in contact with it. Experiment in numerous directions fully supported the idea; but the question arose, would the acridine resist the prolonged solvent action of water, and remain effective for a lengthened period, and in the thin coating of any composition that could be applied as a paint to a ship's side? Opinion varied considerably as to ultimate success when attempted on a practical scale, although laboratory trials had shown that such composition was unacted upon in still water. The first experiment of any importance was made on a small iron barque (the "Cordova"), which sailed from London for the Falkland Islands about the end of January 1882, returning at the end of October, after an absence of nine months, during which her hull had been constantly submerged. Previous to sailing, portions of her plates towards the lower part of the vessel, and where subjected to the greatest wash, had been coated in the ordinary way of applying a ship's paint with acridine composition, prepared in conformity with the patent referred to. He was present on her return to England, and upon the vessel being docked for repainting and repair, he made a close inspection of the portion that had been originally coated with the composition. He found that the paint had remained intact, presenting a smooth and unbroken surface; it had adhered most tenaciously to the iron plates, completely protecting them from the action of the sea. There was no adhesion of barnacle or weed, and the evidence of contained acridine was very manifest on applying the tongue to

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portions of the composition scraped from the sides of the vessel. Mr. B. Nickels.
Subsequent examination showed that there had been little or no loss of acridine, and that the prolonged and beating action of swiftly-running and boisterous seas had failed in removing or washing out the acridine originally incorporated in the paint applied. Since the date of this experiment many others had been made, and were still in hand, with vessels on long sea voyages; and, as far as he was enabled to state, the results obtained had been of a satisfactory character.

It would be difficult perhaps to cite more complete illustrations of the indifference of a substance to severe water action; and the Author might, he thought, rest well assured that his statements concerning this singular tar product were in nowise overrated or exaggerated. As regarded the antiseptic character of acridine, he might mention that it was of high value, extremely small quantities being sufficient to arrest the change in many organic substances prone to rapid decomposition.

Mr. Martin F. Roberts wished to direct attention to a point which Mr. M. F. Roberts.
had influenced engineers in their preference for the so-called "Country oil," viz., that of economy. Engineers would be aware that in drawing up specifications it was usual to stipulate for a certain quantity of creosote to be injected into a cubic foot of timber, usually 6, 8, or 10 lbs., the contractors' price for creosoting being regulated according to the quantity specified; and it thus became necessary for engineers to consider whether, say 8 lbs. per cubic foot of the thick heavy London creosote penetrated as far into the timber as 8 lbs. of the thinner Country oils. He was sure all engineers would agree that it would not; and from his own experience he was able to say that with telegraph-poles, in many cases where 8 lbs. of London creosote per cubic foot had been injected, it had not penetrated more than half through the sapwood; whereas a similar quantity of Country oil would have penetrated completely to the heart-wood, although of course the Country oil would not leave as large a deposit of solid substances in the pores of the timber. It was therefore desirable to consider whether it was better to have the sapwood completely injected with thin oil at a certain price, or the outer portion only injected with thick oil at the same cost; and his experience led him to prefer the complete injection by the thin oil. His ground for arriving at this conclusion was that, although he had met with many samples of creosoted timber in which a portion of the sapwood had decayed where the creosote had not penetrated, he had never met with a case of timber having decayed where the creosote had penetrated,

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Mr. F. M. Roberts. except in one instance in a government telegraph-pole, referred to in the discussion; and even in this case he thought it well to ask if the decay had taken place before or after creosoting? Engineers acquainted with red fir timber would remember that what was called a "foxey pole" was occasionally found, in which, although the outer portion or all of the sapwood might be quite sound, some of the inner portion of the pole had decayed before felling: and it was often a difficult matter even for an experienced inspector to detect such a pole. It would easily be conceived that in such a case the decay might be, and often was, attributed to a defective quality of creosote having been used, instead of to the fact that a portion of the pole was rotten when treated.

The remarks made by the Author under the heading of "The Conflicting Theories of Putrefaction," in which he spoke of the "gaping orifice of a crack produced by the sun in a piece of timber," would appear to specially point to the necessity for the use of a thin penetrating oil, as timber would crack after long exposure in the sun, even if it had been creosoted with the thickest London oil; and in these cases the oil which had penetrated the deepest would be more effective, as it was most likely to have penetrated beyond the depth of the crack. If it were the practice to completely saturate the entire mass of timber with creosote, and if it were found possible to do so in all cases, there would then be no objection to the use of London oils; but as the question of cost had to be considered, and the smallest quantity of creosote per cubic foot which was found to answer the purpose was therefore specified for, the thinner country creosote was preferred owing to its greater penetration weight for weight. In Mr. Coisne's experiments with shavings, the conditions were so totally different to those met with in ordinary practice, that too much reliance should not be placed in them. It was obviously an easy matter to completely saturate shavings either with thick or thin creosote, but with telegraph-poles and railway timber the creosote never penetrated completely through the timber, and it could not be contended that the exclusion of germs alone prevented putrefaction, as if so a coating of tar would prevent decay. What was necessary was that the germs of decay in the timber should also be destroyed, and this could only be accomplished by bringing all that portion of the timber more liable to decay, viz., the sapwood, under the influence of a creosote of considerable penetrating power. If evidence in support of this assertion were needful, it would only be necessary to refer to the fact that engineers strictly barred the use of whitewood timber for telegraph-poles and other purposes,

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owing to its being found impossible in practice to inject creosote into whitewood to a greater depth than ½ or ¾ of an inch from the surface, and whitewood timber so prepared either with London or country creosote was found to decay rapidly. It would appear that the best system of creosoting would consist in first injecting the timber with thin "country oil," then running the thin oil off and filling the cylinder with London creosote, which being forced in by increased pressure would drive the thinner oil further into the timber, and the thicker creosote would hermetically seal the outer pores of the timber. Failing this process, owing to its increasing the cost, it would appear advisable to use thin creosote, and if it was considered that thin oil did not sufficiently fill the outer pores of the timber, the process, at a trifling cost, could be supplemented by giving the timber a coat of hot tar. Mr. M. F. Roberts.

Mr. Greville Williams stated that he regarded the Paper as the most valuable and exhaustive contribution yet made to the literature of the subject. He agreed with Dr. Meymott Tidy and the Author in considering that the value of the carbolic acid in creosote oils had been overrated. He believed that an oil from which the carbolic acid had been removed would sterilize wood, if thoroughly impregnated with it, partly by virtue of the organic alkaloids present, and partly by the protective influence of the heavier oils themselves. He had satisfied himself by careful experiments that the alkaloids exercised a potent influence in preventing the development of bacteria, mould, and microscopic fungi in vegetable infusions. He thought, moreover, that where wood had to be exposed to the action of sea-water, it would be advantageous to use a creosote containing a high percentage of the alkaloids; this could easily be attained by well-known methods. Although the minute quantities of carbolic acid remaining in old creosoted timbers were too small to account for their preservation, he considered it right to say that, by a sufficiently delicate method of manipulation, he had rarely failed in getting evidence of its presence even thirty years after the wood had been creosoted. He found traces of it in eleven out of fourteen specimens which had been creosoted from twenty-five to thirty-two years before. The organic alkaloids, however, which remained were sufficient to allow of quantitative estimation. He thought that no chemist, who had examined very old sleepers for carbolic acid, could come to any other conclusion than that the traces remaining were insufficient for their protection. A point, moreover, of great importance for the proper comprehension of the subject was involved in this almost entire disappearance of the carbolic acid. Mr. G. Williams.

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Mr. G. Williams. If the coagulation of the albumen by the carbolic acid were the cause of the preservation of the timber, how was it that this acid almost entirely disappeared? The instability of the compound, of albumen with carbolic acid, was well known to those chemists who had minutely examined it; nothing more conclusively proved this instability than the disappearance of the carbolic acid. With regard to the naphthalene, he thought it significant that it was only absent from two of the sleepers he had examined. There could, he considered, be no question that naphthalene, although perhaps feeble as a germicide properly so called, was very valuable as a sterilizer; it was insoluble in water, and once in the wood clung to it tenaciously. He was also most decidedly in favour of the removal of all restrictions as to maximum boiling-point, and considered that if the oils were fluid at the temperature of injection (say 100° to 120° Fahrenheit), that was all that was needful. On the whole question, he found himself able to thoroughly indorse the conclusions of the Author and Dr. Tidy, and he considered that specifications which excluded the use of London oils were framed under a misapprehension of the true nature of the condition requisite to afford a good creosote.

Mr. Boulton. Mr. BOULTON had been obliged to be very brief in his verbal reply at the close of the discussion, and as some of the points then raised involved matters of considerable detail, which had also been alluded to in the correspondence, he thought that unnecessary repetition would be avoided if he were to connect his replies to both series of communications in a continuous form. He was gratified at the valuable support which his main propositions had received.

The remarks made by Dr. Tidy, and the views expressed by that gentleman in his recent report to the Gaslight and Coke Co. (Appendix 7) were in principle in accordance with the views expressed in the Paper. The Author, however, believed with Dr. Armstrong that Dr. Tidy, who had been somewhat conservative on the subject of tar-acids, would be led by the logic of facts to accept a much lower proportion than 8 per cent. The "London creosotes" as they came from the still, honest creosotes which had done excellent work, and which constituted probably about one-half of the total supply of this kingdom, did not contain so large a percentage. Some misapprehension still existed on this subject, which the statement of a few facts might remove. In July, 1863, the Author sent to Dr. Letheby a sample of the usual London creosotes, which he was then largely using. Dr. Letheby found it

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contained only 4·37 per cent. of tar-acids. Later on, and during one period of seven years especially, nearly the whole of the tar of the great London Gas-companies, as well as tar from other sources, was contracted for and distilled by the Author's firm. The quantity was probably larger than had ever been treated up to that time by any one firm or corporation, and it therefore formed a sufficiently broad basis for estimation. He would give the quantities during three consecutive years— Mr. Boulton.

1877	Gallons of tar distilled	14,735,404
1878	" " "	15,839,819
1879	" " "	12,690,029

or an average of between fourteen and fourteen and a half millions of gallons per annum. He had found, as stated in the Paper, that the heavy oils distilled from this mass of tar contained on an average from 4 to 7 per cent. of total tar-acids. More recent experiments which he had made upon a large number of London tars—one series in May 1882, another in August 1882, and a third since this Paper had been read—gave similar results. Latterly, the largest of the English gas companies, the Gaslight and Coke Co., had erected works at Beckton, at which they distilled their own tar. It had been assumed that the list of analyses appended to Dr. Tidy's printed report represented the percentage of tar-acids which the London creosotes in their natural condition contained. This, however, was not the case. The samples analyzed by Dr. Tidy contained from 8·2 to 10·2 per cent. of tar acids, but they had been specially treated to "meet the market," created by the modern type of specification by removing from the creosote some of its least volatile parts, those parts containing little or none of the volatile tar-acids. The Gaslight Co.'s creosotes as they came from the still contained on an average 6 per cent. of total tar-acids by the ordinary caustic alkali test. The Author had been enabled to clear up this matter, of which experts would readily detect the importance, owing to the courtesy of the Board and Secretary of the Gaslight and Coke Co. In Appendix 8 would be found the official correspondence on this subject.

He agreed with Dr. Armstrong in the importance of Mr. Pasteur's experiment upon sawdust which was recorded in the Comptes Rendus of the Académie des Sciences for 1863 (56)[1]. It was remark-

[1] The numbers in parentheses in Mr. Boulton's reply refer to the same list of authorities quoted in the Paper (Appendix 4).

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Mr. Boulton. able as an early demonstration of the application of the germ theory to the phenomena accompanying the decay of woody fibre. Dr. Armstrong had alluded to the distinction between wood creosote and tar creosote. Both contained tar-acids, some of which might be identical, or if not identical, isomeric. But tar creosote, if it could be so called, was a complex body; some of the tar-acids it contained differed essentially from either carbolic or cresylic acid, being less volatile, and less soluble in water than either phenol or cresol. This was evident by the experiment recorded in Appendix 5, and it appeared to be confirmed by some recent investigations of Kleinert ("Journal of the Society of Chemical Industry," 29th May, 1884). There was evidently room for much further investigation in this connection; also for a more complete comparison between the "tar-acids of the coal-tar oils and similar bodies contained in other oils."

In relation to the remarks of Mr. W. Foster, the Author must express the hope that that gentleman would continue the very interesting researches of which he had so recently given an account to the Institution in his valuable Paper on "The Composition of Coal."[1] Authentic Tables as to the varying products derived from different kinds of coal, and at different temperatures, were becoming matters of the first necessity in various branches of industry. Mr. Foster had referred to the experiment of Pettigrew (68), alluded to in the Paper. Pettigrew had removed the embalming material from the heart of the mummy by steeping it in alcohol; after which, upon exposure to the atmosphere, putrefaction took place. What the Author desired to point out was that the previous immunity from decay had not been the result of any chemical combination between the antiseptic and the tissue.

A jarring note had been struck by Mr. Bamber, who had represented "the whole secret of the Paper" to consist in "the Author's idea . . . . . that nothing should be left in the creosote which it would pay him better to take out;" an object foreign to the declared aim and intention of the Paper. The Author had not approached the subject from the commercial point of view—a fact which the President had so gracefully recognized. It might, however, be opportune to state that he was not at present commercially interested in any manufacture which caused carbolic acid to be "taken out" of the creosote oils, although he was largely interested in the success of prepared timber as an engineering material, and therefore in the choice of the best antiseptics for that purpose, whether

[1] Minutes of Proceedings Inst. C.E., vol. lxxvii., p. 162.

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obtained from the creosote oils or from other sources. Mr. Bamber's figures as to the comparative commercial values of creosote oils and carbolic acid, recalled to memory the well-known comparison between the value per ton of iron ore and of steel watch-springs. The manufacture of pure carbolic acid was a long and costly process, of which the first cost of the crude material formed an altogether insignificant item. Nor was so low a price as 2*d.* per gallon for creosote either "proverbial" or usual. But it would be found in the long run that the consumer had to pay the commercial value for everything which the creosote contained, and it was therefore best to discuss upon scientific and practical grounds the substances which the engineer should require it to contain. It was one of the main objects of the Paper openly to point out by diagrams and detailed descriptions the principal substances contained in the coal-tar oils, to draw attention to their properties, and to state their uses for various manufactures, so that, for the purposes of timber-preserving, engineers might be in a position to "prove all things, hold fast that which is good." Mr. Bamber was mistaken as to facts in his allusion to Dr. Letheby's specification, and that of Dr. Tidy. Dr. Letheby's specification, drawn up under instructions from Mr. Meadows Rendel, M. Inst. C.E., in 1865, for the use of the East Indian Railway Company, stipulated that the creosote was to yield to a solution of caustic potash, not less than 5 per cent. of crude carbolic, and other tar acids. Dr. Letheby never increased that quantity. Dr. Tidy had increased, and not as Mr. Bamber supposed, diminished the percentage of tar-acids mentioned by Dr. Letheby. Mr. Boulton.

Mr. Bamber complained that no facts or data had been given respecting Dr. Tidy's experiments on naphthalene. But the Paper contained a reference to a printed report of Dr. Tidy, deposited in the library of the Institution (30) (54), wherein was a full account of these experiments. They were also recorded and approved of by Dr. Lunge, of Zurich, in his learned work upon "The Distillation of Coal Tar," pp. 204 to 206 (47*a*) (55*a*). Amongst other authorities who after investigation differed from Mr. Bamber in admitting naphthalene as an ingredient in the timber-preserving oils, were the late Mr. Bethell, Mr. Burt, Professor Sir Frederick Abel, Mr. Forestier, for the French Government (40), Mr. Coisne, for the Belgian Government (22), &c. Mr. Bamber had once stated to an eminent engineer, in a report upon a creosote highly charged with naphthalene, that timber impregnated with such an oil would, "within a very short time of the timber being in India, lose 5 lbs. out of every 10 lbs. put into the timber here merely by

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Mr. Boulton. escape of naphthalene." Dr. Tidy's experiments with timber injected wholly with napthalene, and subjected to a temperature of 130° Fahrenheit, proved that these apprehensions were unfounded (Appendix 7). But it was now related by Mr. Bamber that in his own experiment a piece of wood impregnated with a creosote of the type which he preferred, and containing 20 per cent. of tar-acids, lost in four weeks 42·33 per cent. of the oil taken up. Mr. Bamber's record of his own experiment was very instructive. He tried two kinds of creosote against each other. One, which might be called specimen A, was "full of naphthalene," but the percentage of that body was not stated. It contained 10 per cent. of tar-acids. Specific gravity not named. With this oil a piece of deal 3 inches by 3 inches by 8 inches was impregnated. The other, which might be called specimen B, was a "country oil," specific gravity 1·045, containing 20 per cent. of tar-acids. With this oil a piece of deal 3 inches by 3 inches by 6 inches was impregnated. Specimen A was alluded to as "Mr. Boulton's own oil" and "the Author's London creosote"; but to these appellations he demurred, as he never used a 10 per cent. creosote unless required to do so by specification, and the London oils did not in their natural state contain 10 per cent. of tar-acids. Therefore A, although it might come from his works, would be a mixture of London and Country oils. But although in the Author's judgment too volatile, yet the 10 per cent. specimen would be less volatile than the 20 per cent. Therefore, the Author preferred A to B. Where a large issue was staked upon a single minute experiment, accuracy of result should be ensured by the most minute precautions. It was not explained why the two pieces of deal were not cut to the same size, a circumstance which affected the conditions both of absorption and of evaporation. Nor were the specific gravities of the two pieces of wood stated. Of two pieces cut from the same log, one piece of wood would frequently absorb, under the same conditions, a very much larger quantity of fluid than the other. However the results as stated might be calculated as followed :—

A. Piece of wood, capacity 72 cubic inches, absorbed 1,020 grains of creosote = 3·49 lbs. per cubic foot.

B. Piece of wood, capacity 54 cubic inches, absorbed 1,785 grains of creosote = 8·17 lbs. per cubic foot.

But no pressure was used, and engineers would recognize that the experiment failed to reproduce the conditions of the ordinary creosoting cylinder. It was well known that without pressure light oils penetrated timber more easily than heavy oils. In like

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manner the adulterating substance, bone oil, penetrated more readily than creosote; solutions of metallic salts more readily still; and water more readily than all. But it was "light come, light go"; those which penetrated most readily were generally the least permanent. The main object of the engineer was not to select the fluid which gave the contractor the least trouble to inject. He desired to select the antiseptic which was likely to be the most efficacious and the most permanent, and he required the contractor to provide efficient apparatus, and to inject under pressure a stipulated quantity by weight. Sleepers and large logs of timber were injected without difficulty with creosotes of a heavier type than either of Mr. Bamber's samples, and to the extent of 10 lbs. and 12 lbs. per cubic foot. Small pieces of wood could be easily gorged with creosote. The Author had recently injected some fir paving-blocks 6 inches by 6 inches by 3 inches, with 22 lbs. per cubic foot of ordinary heavy London creosote, containing about 5 per cent. of tar-acids. Mr. Bamber exposed his specimens to evaporation on a mantelshelf at a temperature never above 70° Fahrenheit, and generally between 40° Fahrenheit and 50° Fahrenheit. In four months A had lost 47·75 per cent., and B had lost 42·33 per cent. of the creosote put in. If this could be taken as a normal result, engineers would hesitate as to employing either type of creosote. No doubt both were too volatile. But it should also be borne in mind that the injection was imperfect; to use Mr. Bamber's expression, it was only "skin deep." As regarded the comparative evaporation of the two specimens, however, the result was extremely valuable. It was well known that the evaporation of fluids (except when in a state of ebullition) was in proportion to the surface exposed, and not to the bulk of the fluid. This point Mr. Bamber appeared to have forgotten; he had exposed A, the creosote he disliked, to a wider evaporating surface than that to which he had exposed B, the creosote which he preferred. The position on the mantelshelf in which the pieces of wood were placed was not stated. But supposing them to have been suspended, say by a thread, so that all the surfaces were exposed to evaporation equally, the results might thus be calculated:— Mr. Boulton.

A. Piece of wood, the sum of whose superficies was 114 square inches, lost 487 grains = 4·29 grains per square inch of exposed surface.

B. Piece of wood, the sum of whose superficies was 90 square inches, lost 575 grains = 6·39 grains per square inch of exposed surface.

If, however, each piece of wood had been placed with one of

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Mr. Boulton. its sides in contact with the mantelshelf, so that one surface was protected from evaporation, the calculation became slightly modified, so that A would have lost 5·41 grains, and B 7·98 grains per square inch exposed. If the specimens had been placed on end, then A showed a loss of 4·64 grains and B of 7·09 grains per square inch. Mr. Bamber had therefore been mistaken as to the comparative volatilities of naphthalene and the tar-acids, as proved by his own experiment. B, the creosote with 20 per cent. of tar-acids, had lost about 50 per cent. more than A, the creosote with 10 per cent. of tar-acids and "full of naphthalene." Had it been otherwise, every chemical treatise describing the properties of these bodies, would have to be re-written. The statement that part of the loss of specimen B was due to the fact that some of the oil drained out of it, which it was said "was not fair" to that specimen, gave rise to the rejoinder, was it quite fair to a timber-preserving process that a type of antiseptic should be recommended which "drained out" with so little provocation? This part of the discussion might almost appear trivial, were it not for the fact, confirmed by many special instances in the Author's experience, that whenever these light oils had been used exclusively, whether for marine work or for railways, complaints invariably arrived, sooner or later. Oils of so light and volatile a nature lost a large portion of their bulk, which evaporated or drained out in the creosoting-yard, on the export-ship, and on the permanent way in India and elsewhere. An experiment, easy to carry out without any laboratory apparatus, might be tried by any one interested in this subject. Take three saucers or shallow dishes; place in one saucer 200 grains of pure carbolic acid (crystallized), in the second 200 grains of pure cresylic acid, and in the third 200 grains of pure naphthalene. Expose them side by side in any room, and at any ordinary temperature. The crystals of carbolic acid would liquefy in a few minutes, owing to the avidity with which that body absorbed moisture from the atmosphere. In a few weeks time (varying with the temperature) the carbolic acid would have entirely disappeared by evaporation. By that time the cresylic acid would have lost about half its bulk. When the whole of the cresylic acid had also evaporated, the naphthalene in considerable bulk, at least one-half of the original weight, would still remain, an easy victor in the trial of endurance.[1] The evaporation was greatly retarded by the incorporation of those bodies with the

[1] This experiment was carried out on a mantelshelf at the Institution of Civil Engineers in August, 1884, with the result indicated by Mr. Boulton.

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less volatile oils, and by their being driven into the cells of the timber. But the evaporation must necessarily take place in proportion to the respective and recognized volatilities. Mr. Boulton.

Allusion had been made by Mr. Bamber to "charred oil," and he presumed that it was a residue of anthracene manufacture. The Author in the course of his experience had never met with "charred creosote," except indeed as a result of over-heating in a laboratory experiment; nor was he acquainted with any ordinary process of manufacture by which it could be produced. Creosote oils were distillates; whatever the heat in the still, the residuum might become carbonized, but not the substances which came over in the form of vapour. Anthracene or para-naphthalene had been denounced by the creosote specifications of the theorists at a time when it was considered worthless for any purpose; it was taken out of the creosote by every tar-distiller in England, whether in London or country, and was now of value for the manufacture of alizarine. The removal was effected by a simple process of filtration; the resulting oils were the green oils, the best part of creosote for timber-preserving, fluent and rich in alkaloids (1), (2), (31), (32). How could they become "charred oils"?

In the illustration, drawn from a fire-engine, it was forgotten that a fire might break out a second time, and that if a fresh supply of water were not available, the building would be consumed. Carbolic acid evaporated rapidly from timber, and it had been proved that it left no permanent effects behind. When the sleeper was placed in the permanent way the supply of the antiseptic could not be renewed, and the timber would rot if more stable antiseptics were not present in the shape of the heavier oils.

As regarded naphthalene colours Mr. Bamber was also mistaken. They were very successful as a manufacture, and their use was largely increasing. He accused the Author of "condemning Country oils," and of saying that they "were not good for creosoting timber." In the Paper the exact contrary was stated. The Author advocated the use of both London and Country oils (p. 119), and he habitually used large quantities of both. What he condemned was the use of oils, whether London or Country, which were so manipulated as to contain a large proportion of volatile substances at the expense of the more durable, and therefore for this purpose more valuable antiseptics. Were Mr. Bamber's theories carried into practice, about one-half of the creosote manufactured in England, the enormous bulk of the "London oils," would be excluded from use by the timber-preserver. Nevertheless they were precisely the

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Mr. Boulton. creosotes which had given the most unmistakably good results, whether, as in the case of the earlier Indian sleepers, and of the sleepers of the Western Railways of France, the percentage of tar-acids had been proved to be small, or whether, as was the practice of the Belgian government, the tar-acids had been altogether and avowedly struck out of the specification.

In reply to Professor Voelcker, he desired to state that he had purposely abstained from connecting the names of administrative bodies with questions of controversy. He was not aware of any specification officially issued by the War Office which bore on this subject; but it was known that the distinguished chemist of that Department had been consulted by various Administrations, who could have had no other object in view than to obtain the best engineering material. The views of Sir Frederick Abel on all the most important points of a creosote specification were substantially the same as those of Dr. Tidy and of the Author. And what the Author considered to be the most important points were, 1st, that the presence in considerable volume of the heavier and least volatile distillates, *i.e.* those distilling at or above 600° Fahrenheit, must not merely be tolerated but insisted upon. That naphthalene, and the other usual semi-solid constituents, should be admitted, provided they were completely fluid at the temperature to which the creosote was raised when injected into the wood. It was known that these views had not been adopted by the Crown agents for the colonies, but he hoped that this discussion might be the means of clearing away many misconceptions. Respecting the point which he considered subsidiary to the other two, although not unimportant, viz., the percentage of tar-acids, Sir Frederick Abel, as well as Dr. Tidy, had recently recommended a reduction, and the last word had not been said on this question. Professor Voelcker was mistaken in thinking that Dr. Tidy had recommended 8 per cent. of carbolic acid. The 8 per cent. was of total tar-acids, including carbolic, cresylic, and all other tar-acids which could be removed by a specified solution of caustic soda. Dr. Tidy, in his report to the Gaslight Co., mentioned his reasons for not stipulating for a fixed quantity of carbolic acid. Whenever any stated quantity of this body had been mentioned in specifications by English engineers, it had been fixed at one-half of the total tar-acids. Hence the quantity had varied from 2½ per cent. to 5 per cent., the latter being the largest quantity of crude carbolic acid which the Author had ever known to be required by any specification issued in this country. He might be permitted to express his satisfaction that Dr. Voelcker had recently joined the

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ranks of investigators into the properties of creosote oils, but he was sure that so distinguished a chemist would be the last to depreciate the experiments and experience of the numerous chemists and practical men who had placed the results of their labours on record. It could surely have only been by some misconception that Dr. Voelcker recommended an entirely new departure by asking for 10 per cent. of carbolic acid in creosotes used for young timber or sap-wood, although he admitted the probable superiority of the heavier oils for timber intended for railway sleepers and other engineering purposes. Dr. Voelcker had not produced the results of any original experiments in support of his views. The typical experiments which he asked for had been tried and recorded; they proved that carbolic acid and the lighter tar-acids were not reliable as durable antiseptics for timber (78), (22), (102). Engineers were familiar with the preparation of young wood and sap-wood as well as with that of older timber. The same creosotes were always used for both, and with complete success. It had been clearly established that the heavy oils preserved sap-wood from decay. It would be remembered by many members of the Institution that the late Mr. Bethell had even advocated the use of young wood in preference to older timber, because the sap-wood absorbed the creosote so readily, and that Mr. (now Sir John) Hawkshaw had combated this idea, not from any doubt of the preservation of young wood, but upon the ground that the engineer must choose for many purposes the kind of timber best adapted for resisting impact or heavy strains. Amongst the numerous successful specimens of creosoted wood which had been exhibited at the Institution during the discussion, and which had been taken from various railways after periods of endurance varying from sixteen to thirty-two years, nothing was more striking than the perfect preservation of the sap-wood, although careful analysis had shown that the heavy oils, and not the tar acids, were the enduring agents of preservation (28). The allusion of Dr. Voelcker to telegraph-poles had elicited much practical information. Nothing could be more conclusive than the evidence of Mr. Preece as to the behaviour of the young timber, surrounded by its girdle of sap-wood, which was used for telegraph-poles in this country. The Author had been responsible for the creosoting of a large portion of the poles alluded to by Mr. Preece; these had as a rule been prepared with the usual London oils. But it was only right that he should state another circumstance. He believed that the success of the poles, creosoted for the Post-office Telegraph Department, was largely in- Mr. Boulton.

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Mr. Boulton. fluenced by the care taken by that Department in the seasoning of the timber. The date of delivery of the poles, landed and stacked at the creosoting yard, was a matter of contract, but there was no fixed date for the creosoting. On the contrary, the engineer did not allow them to be creosoted until he pronounced them to be dry, and ready for the process. Sixteen years ago, at a meeting of the Institution,[1] he had urgently recommended the adoption of some such method for ensuring the proper seasoning of timber. The very interesting and satisfactory evidence of Mr. Bouissou, the Engineer of the Western Railways of France, confirmed the experience of Mr. Preece, both as to the satisfactory results of creosoting, and also as to the great importance of seasoning before creosoting; the precautions adopted for the latter purpose by the French company being substantially the same as those of the English administration. With reference to the preparation of telegraph-poles, a very valuable Paper had been contributed by Mr. William Langdon to the Society of Telegraph Engineers on the 25th of March, 1874.[2] Mr. Langdon had also contributed to this discussion, and had confirmed by his experience many of the views entertained by the Author. With regard, therefore, to the observations of Dr. Voelcker as to green or unseasoned timber, the Author would add the results of his own long and varied experience in this and other countries, by saying that the attempt should never be made to inject creosote, or any other oily substance, without previously, or at the time of the operation, expelling watery moisture. Timber should not be felled whilst the sap was in it.

As regarded the effects of living organisms, and the introduction of their spores through cracks in the wood, the views of Mr. Carruthers entirely agreed with those expressed by the Author. But what was the remedy? The botanical aspect of the question had not been lost sight of, from the days when Dean Buckland and others discussed at this Institution[3] the question of timber preparation from that important stand-point, and it had not been overlooked in the modern systems of injection. Exogenous trees, whose annual growth took place by the formation of concentric layers of vascular tissue added externally, furnished the timber with which engineers had almost exclusively to deal. The softer and younger wood, containing the greatest portion of albumen,

[1] Minutes of Proceedings Inst. C.E., vol. xxvii., p. 564.
[2] Journal, vol. iii., p. 181.
[3] Minutes of Proceedings Inst. C.E., vol. ix., p. 48.

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Mr. Boulton.

was on the outside; it was more liable to decay than the harder portions. It was the chief merit of the system of injecting under pressure that it precisely met this difficulty. The softer parts absorbed more of the antiseptic than the rest, the pressure followed the line of least resistance, the antiseptic fluid gorged the sap-wood, and penetrated to all cracks or shakes. There was but little analogy between this method and the application of a surface coating of pitch, as although he recommended by preference oils of a heavy character, and containing semi-solids, the whole of these bodies were perfectly liquid at 100° Fahrenheit, the temperature to which they were usually subjected at the time of injection. On cooling, they solidified, not on the surface merely, but within the pores of the timber, which they sealed up against the incursion of the agents of decay. Mr. Carruthers had referred to the experiments of the celebrated Dr. Koch. The researches of Koch, and of other German scientific investigators, were very damaging to the claims of carbolic acid as a germicide, and as a coagulator of albumen. In his treatise 'Ueber Desinfection' (81*a*), Dr. Koch deduced from his careful and laborious experiments minutely described, that the value of carbolic acid was greatly limited as a germicide, and that for the destruction of spores it was altogether useless, being almost without action; but that it could be used to destroy micro-organisms free from spores. This was when used in a watery solution; still stronger was his opinion as to an oily solution. He stated that in solutions of oil or alcohol, carbolic acid did not exhibit the slightest antiseptic action. ("In Oel, oder Alkohol gelöst äussert die carbolsäure auch nicht die geringste desinficirende Wirkung.") To this, the remarks of Dr. Sansom had already pointed (90). It must be remembered that it was in an oily solution, *i.e.*, dissolved in the tar oils, that carbolic acid was applied to timber. G. Wolffhügel and G. v. Knorre followed up Koch's investigations, and spoke of the inactivity of an oily solution of carbolic acid; of its inferior powers of penetration into porous solids, and of its inferiority in the destruction of fungi (94*a*). F. Boillat, who followed up the experiments of Koch in the laboratory of Professor Nencki at Bern, found that albumen, when completely coagulated with an excess of carbolic acid, formed no permanent combination therewith. He was able to wash out on a filter the whole of the carbolic acid from the albumen precipitate, after which, upon exposing it to the atmosphere during forty-eight hours, the albumen became putrid (80). Mr. Carruthers had spoken of the presence of free crystallized carbolic acid in the cells of a small piece of a wooden hurdle. But carbolic acid would

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Mr. Boulton. not crystallize out of the oils holding it in solution; it could only be obtained in that state of purity by a long and complicated chemical process, and the crystals would immediately liquefy when exposed to the atmosphere. The minute particles seen by Mr. Carruthers were probably naphthalene, or one of the other semi-solids of the higher distillates of coal-tar. The condition of this hurdle corresponded exactly with that of enormous masses of successfully creosoted timber as typified by the samples exposed during this discussion (Appendix 6), and the Author thought that the final question of Mr. Carruthers had been fully answered by many authorities quoted in the Paper (22), (28), (30), (31), (55), (78), (80).

In reply to Mr. C. de Laune, the Author would remark that his Paper had a much wider object in view than the mere question of carbolic acid; the presence or absence of that body would not explain Mr. de Laune's difficulty. No honest creosote made from coal-tar, whether London or Country oil, whether with much or little tar-acid, contained any ingredient which could injure timber; the only question was, which of those ingredients were most efficacious and most durable. The question as to which was the easiest to put into the timber was of much less importance. Some small pieces of hurdles, &c., had been shown during the discussion, and alluded to by Dr. Voelcker, Mr. Carruthers, and Mr. de Laune; Mr. E. A. Cowper had detected the reason why one had succeeded and the other failed. The first had had plenty of creosote put into it; the others but very little. Mr. de Laune had made a detailed statement to the Author, which was briefly as followed: That he had been in the habit of preparing different kinds of timber of various densities, and frequently in a wet or unseasoned state by boiling the wood in creosote in open tanks and without a thermometer; and that he did not keep the timber in the tanks more than twelve hours, as a longer operation rendered it brittle—a very significant fact. He said that he had not latterly superintended these operations personally, and that he did not regard the process as a scientific one, but thought that it could be carried out by odd hands, old men, or boys. A good many years ago, the Author had had considerable experience in preparing timber in open tanks with corrosive sublimate, sulphate of copper, and also with creosote. The time for leaving the timber in the tank, to be injected by the metallic salts in watery solution, which penetrated more readily than creosote, was generally calculated at about twenty-four hours for every inch in thickness of the wood. With the creosoting process it was

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essential that the water in the timber should be first got rid of; Mr. Boulton. the presence of the water prevented the entrance of the creosote oils. Even with the cylinder-process, where the oil was driven in under pressure, engineers insisted upon the timber being dry, and they weighed it before and after the operation, to check the quantity of creosote injected. With the open-tank system more care, and not less care, was necessary than with the superior apparatus. But soft young timber, if properly seasoned and then subjected to creosote at a moderate heat, could without difficulty be made to imbibe a sufficient quantity of creosote of any kind manufactured in this country. But if the timber was wet, it was not amenable to treatment by creosote in open tanks at a moderate temperature, and if the creosote was raised to a temperature even approaching to its boiling-point, which was about 400° Fahrenheit, it would cause the timber immersed in it to become as brittle as a carrot. Timber should not, under any circumstances, be subjected to a higher temperature than 250° Fahrenheit. It would, therefore, appear that Mr. de Laune's difficulties were to be explained by his methods of operation. He had told the Author that he had for many years procured all his creosote from the same works, a small local manufactory, where the tars of the district were distilled. It had been ascertained that the creosotes manufactured at the works in question had not essentially varied in type, whilst even as regarded carbolic acid, if the analysis quoted by Mr. de Laune was correct, the quantity contained in the sample was considerably above the average, although this was a point to which the Author attributed but little importance. He was surprised to find, in the report accompanying the analysis alluded to, a statement to the effect that "good creosote should yield quite 75 per cent. of volatile oils (*sic*) containing 10 to 15 per cent. of crude carbolic acid." No creosotes used for timber-preserving, under any specification, had ever been required to contain more than from 2½ to 5 per cent. of crude carbolic acid. The recommendation of "volatile oils" was a mistake which was obvious to all experts; but it might have a bad effect in encouraging the use of some of the worst adulterants, substances sold as creosote which were not derived from coal tar at all. The report, although issued from the laboratory of the Royal Agricultural Society, was signed for, but not by Dr. Voelcker. The Author had understood that Dr. Voelcker was at the time absent owing to illness; he would not therefore have alluded to it but for the fact that this report had been brought so prominently

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Mr. Boulton. into notice by Mr. de Laune, and that extracts from it had been published in an agricultural journal.

The Author had used creosoting for farm purposes, for fences, hurdles, and for many years also for piles and fences for his wharves. He always used for himself the type of creosote he recommended to others, and it had proved invariably successful in his own case.

The Author was asked by Mr. Cleminson why he had not alluded to the process of Mr. Blythe. If by Blythe's process was meant the attempt to introduce the creosote oils, or any part of them into timber in the form of vapour, the subject had been fully treated in the Paper. For the operations described as having been carried out for the Western Railways of France, the apparatus used was supplied by Mr. Blythe. The experiments of Mr. Seidl were described by him as having been carried out by "Blythe's process." Engineers in England had recently had an opportunity of witnessing similar experiments at the works of Messrs. Connor, at Millwall. After the dismantling of these works, the Author had purchased the greater part of the machinery for the purpose of adapting it to his own processes, so that he had again had an opportunity of studying the question. By slow evaporation fluids gradually volatilized at temperatures much below their boiling-points. But pressure from their vapours could only be obtained at temperatures exceeding their boiling-points. Thus water gradually evaporated even from a frozen surface, but no tension of its vapour could be produced except at a temperature exceeding its boiling-point, 212° Fahrenheit. The boiling-point of the creosote oils ranged from about 400° to 760° Fahrenheit, that of carbolic acid when separated from these oils being 360° Fahrenheit, and of cresylic acid 390° Fahrenheit. Now, it was well known that timber for the purposes of the engineer was injured and rendered brittle and unsafe at a temperature much exceeding 250° Fahrenheit. How then could those tar products be introduced under pressure into the timber as vapour, whether accompanied or not by super-heated steam, without injuring the timber? Either the temperature must be raised above danger-point for the wood, or nothing but the vapour of water would be driven into it. This applied to the first part of the process. Of course, if it was followed up by an injection of the creosote oils in the usual manner, this second part of the process covered the deficiencies of the first operation. The presence of any of the components of the tar-oils could be detected in the timber by chemical tests. When specimens of wood had

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been produced, which had been prepared by the injection of tar-oil vapours in sufficient quantity to have a practical value in the preservation of timber, and at a temperature not exceeding 250° Fahrenheit, the Author would be very glad again to give his best attention to this part of the subject. Mr. Boulton.

He was glad to be able to reply to the question of Mr. Lawford, with regard to the Midland Railway Company. In 1866, at a meeting of the Institution, Mr. Crossley, the engineer of that company announced that, although he admitted that creosoting stopped decay, he had given up that process from a calculation of economy based on the assumption, that with very heavy traffic like that which prevailed over the lines of his company, the sleepers were worn out by hard work before they had time to decay.[1] The Author would suggest that incipient decay of unprepared sleepers often set in at a very early period of their service, especially through cracks and bolt-holes; the fastenings of the chairs thereupon became loosened, and the mechanical destruction of the sleeper hastened. But Mr. Lawford would be glad to hear that the Midland Railway Company had again adopted creosoting; they had had large quantities of sleepers creosoted during the last few years.

In reply to Mr. Roberts, the Author had never found any difficulty in completely saturating the sap-wood with the London oils where the timber had been sufficiently dry. Mr. Coisne's experiments with shavings were for the purpose of ascertaining what kind of creosote lasted best, and he effected a complete saturation both with the thin oils and with thick oils. The thinnest oils did not preserve the woody fibre from rotting even with so good an injection, whilst the heavier oils did. *A fortiori*, the thinner oils would be by themselves still more unreliable with the inferior injection carried out in practical operations with timber. It must also be borne in mind that Mr. Coisne did not stop at these experiments, but had confirmed them by twenty years' subsequent treatment of timber on a very large scale, for the Belgian State Railways. The chapter in Mr. Coisne's 1871 pamphlet upon the choice of creosote oils was a most interesting and practical one (22).

With reference to the Author's process for removing water from the timber at the time of creosoting (Plate 7), the following experiment had been carried out at his works since the Paper had been read.

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[1] Minutes of Proceedings Inst. C.E., vol. xxv., p. 415.

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Mr. Boulton. Six square fir-sleeper blocks, each 8 feet 11 inches by 10 inches by 10 inches, saturated with moisture, were cut into 10 inches by 5 inches sleepers. One sleeper, A, from each block was prepared by the new method, the corresponding sleeper, B, from the same block, by the old method, so that in each instance the results with the two halves of the same log could be contrasted. Care was taken to choose blocks having the heart in the centre, and with the texture of the two halves as nearly as possible similar.

From the six sleepers, A, water was withdrawn by the new process to the extent, ascertained by weighing the water, of 120 lbs.; yet the sleepers, when withdrawn from the cylinder after the process was completed, weighed 155 lbs. more than when put in, thus showing that they had absorbed 275 lbs. of creosote. As their total cubic contents were 18·57 cubic feet, their average loss of water was 6·45 lbs. per cubic foot; their average gain of creosote was 14·8 lbs. per cubic foot.

The six sleepers, B, were creosoted by the ordinary process. Being, like the others, very wet, and having no moisture extracted from them, the results of their being weighed before and after creosoting showed an absorption of 116 lbs. of creosote only, or an average of 6·29 lbs. per cubic foot. The separate absorptions of these six sleepers were as followed: 9·04 lbs., 4·52 lbs., 2·9 lbs., 6·13 lbs., 9·36 lbs., and 5·49 lbs. per cubic foot respectively, thus illustrating the uncertain results of creosoting timber when too wet by the ordinary method. They were placed in the cylinder with a charge of ordinary dry sleepers, which took up on the average rather more than 10 lbs. of creosote per cubic foot.

The result with sleepers A was interesting, as it showed that by the new process wet timber could have its moisture at once removed, and a large quantity of creosote injected without difficulty. All twelve sleepers, both A and B, were afterwards cross-cut at 6 inches, 9 inches, 12 inches, and at 4 feet 6 inches from their ends, the corresponding sections of A and B being contrasted and photographed. The sleepers A were found not only to have absorbed a large quantity of creosote, but the creosote was much more evenly distributed than was the case with sleepers B.

Might the Author be permitted to sum up the evidence which had been produced during the discussion as to the best class of antiseptics for timber? Both engineers and chemists would probably agree with him that after forty-five years' discussion of this engineering problem the time had gone by for dogmatic assertion, unsupported either by experiment in the laboratory or by recorded experience in engineering works. In the Paper he had called the

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germ theory a severe but salutary test for these antiseptics. As a matter of fact the subject had received valuable elucidation, from the labours and discoveries of a number of eminent men, who had studied the physiology of the bacteria. In the application of the remedies, however, the operations of the timber-preserver diverged from those of the physician to the human body. In combating those terrible enemies the bacteria, which were pathogenic to animal life, the great difficulty was that many of the remedies effectual against the bacteria interfered with the vital functions of the patient. On the other hand, the physician could repeat remedies whenever the malignant symptoms reappeared. Therefore antiseptics, more or less volatile, were sometimes more useful to the physician than others of a more permanent character, because they did not accumulate in the system of the patient. In preserving timber the problem differed materially. The vital functions of the plant had ceased; stronger poisons, and substances which clogged up the cells and tissues, could be employed, provided always that they were of such a nature as not to injure the structure of the wood. But the remedy must be applied once for all. In the majority of cases where timber was once placed in engineering works the supply of the antiseptic could not be renewed. Therefore, the very first condition was that the antiseptic should be of a permanent constitution. Let this rule be applied to the evidence offered during the discussion. Antiseptics for timber had been described: 1st, as coagulators of albumen; 2nd, as germicides; 3rd, as sterilizers, rendering the cells of the wood unfit for the development of fungi or bacteria; 4th, as germ-excluders, closing the entrances against the intrusions of the enemy. Mr. Boulton.

Was not too much value still attached by some to the coagulation of the albumen in wood? Albumen formed an extremely small portion of the wood; in fir it varied from 0·5 to 0·9 per ceut. Those parts of the timber containing the smallest portions of albumen were nevertheless liable to decay; the mere coagulation of the albumen did not protect the bulk of the timber from destruction. Did coagulation preserve even the albumen itself from destruction? Sansom (90*a*), Angus Smith (91), and other authorities found that it did not. The Author took a hard-boiled egg, a very complete specimen of coagulated albumen, removed the shell, and exposed it to the sea breezes on a high point of the Atlantic shore of the island of Mull. In a few days signs of putrefaction were visible; in eight days the albumen was coated with various species of micrococcus cromogenes and other

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Mr. Boulton. agents of destruction. The egg had become a mass of corruption. Coagulation had not protected albumen from putrefaction. What was the result when coagulation was produced, not by heat, but by the action of an antiseptic body? Did not the result depend mainly, if not altogether, upon the germicide properties of the antiseptic, and upon its abiding presence? Or, thus produced, did coagulation *per se* effect a new combination with permanent results? In the case of carbolic acid, a host of investigators said, No. Their experiments appeared to prove that carbolic acid was volatile in the air, soluble in water, and that its compounds were not stable (80 to 91). Boillat, in his experiments, realized the extreme conditions desired by those theorists who thought that carbolic acid had a permanent effect upon timber; he produced a perfect coagulation of albumen with an excess of carbolic acid. Yet a mere washing with water removed the whole of the carbolic acid, and the albumen putrefied on exposure to the air. Carbolic acid, therefore, would appear to have had no permanent effect upon albumen (80). The Author agreed with Dr. Bernays that if coagulation by carbolic acid were desirable, 2 per cent. of that body might be retained; but, having in view the foregoing evidence, what was the value of the coagulation theory at all as applied to timber-preserving? There had been some idea that carbolic acid lingered in the timber in some unrecognized form. The Author had had occasion to test sleepers a few weeks after creosoting; if this were done before the carbolic acid had time to evaporate, it could be found in the wood by the ordinary tests, and a quantitative analysis made. On the other hand, Dr. Tidy, who was not unwilling to find it in combination, had searched for it after twelve months, and had not found it by the ordinary tests, that is, in sufficient quantity to have any practical result. But whenever it was present there were tests subtle enough to detect it, even in such infinitesimal quantities as to have no practical value, as was evidenced by the experiments of Mr. Greville Williams (28). Notwithstanding theories and experiments, did carbolic acid, when put into timber, do any good there? Mr. Coisne (22), Mr. Greville Williams (28), and the Author, not only never found it to have contributed to the success of old creosoted timber, but Mr. Coisne's experiments went further still. He injected woody fibre with light oils and an excess of tar acids, and the woods rotted, whilst the woods creosoted with heavy oils, and without any tar-acids, were preserved (22).

There was one point respecting which there had been a concensus of opinion on the part of all who had taken part in the

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discussion, namely, that for the preparation of timber, creosoting had been undeniably more successful than corrosive sublimate, sulphate of copper, or chloride of zinc. Could this be at all due to carbolic acid? How was this possible, when a host of authorities proved that carbolic acid was less permanent in its effects than the three metallic salts alluded to, and very considerably less powerful as a germicide than corrosive sublimate or sulphate of copper (Koch, 81*a*; Boillat, 80). In a valuable work upon bacteria by Magnin and Sternberg (2*a*) there was a long list of antiseptics, with a statement as to their comparative potency as germicides, compiled from the latest authorities. Carbolic acid was low in the scale. Dr. Sternberg gave the strength of solutions of different kinds which had been found efficacious in preventing the development of the septic micrococcus, the following amongst many others:— Mr. Boulton.

Corrosive sublimate	1	part in	40,000
Sulphate of copper	1	„	400
Chloride of zinc	1	„	200
Carbolic acid	1	„	200

These were in watery solution. To this must be added the statements that in oily solution the antiseptic power of carbolic acid was diminished, according to Sansom (90) and Angus Smith (91); altogether it was nil according to Koch (81*a*). It was evident that there was a vast accumulation of scientific evidence in confirmation of the continually reiterated statements of those practical men, who had had the largest and longest experience in preparing timber, to the effect that it was not to carbolic acid, but to other substances contained in the tar-oils, that the superiority of the creosoting process over the other three methods was due. Mr. Lowe was well known as one of the highest scientific and practical authorities upon the tar-acids, and he had given much valuable information in his communication to the Institution. On the other side the absence of evidence was even more remarkable than many of those interested in this subject would perhaps have anticipated. No chemist had brought forward even a laboratory experiment in proof of any permanent effect of carbolic acid upon albumen. No practical man had produced a proof that that substance had had any lasting effect upon timber. The Author submitted that the claims of carbolic acid as an antiseptic for timber had not been proven.

What, then, were the substances in the creosote oils which had

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Mr. Boulton. ensured the superiority of that process over the others? If the Author were asked the question, he would refer the engineer once more to Plate 6 and Appendix 1, and would remark that the object being the prolonged preservation of timber, antiseptics should be chosen which remained longest in the timber. That part of the diagram on Plate 6 which represented the different constituents of the creosote oils, showed a gradation from the lightest and most volatile bodies at the carbolic, or left-hand end of the scale, up to the least volatile and most permanent bodies at the right-hand end. Divide the bulk of the oils roughly in half. Would the constituents of the right-hand half of themselves ensure the preservation of the timber? Yes, excellently well (22). They contained germicides and solidifying materials; they were both sterilizers and germ-excluders; they would not evaporate, except at an enormously high temperature. Nevertheless in their united bulk they were perfectly fluid at a temperature of 100° Fahrenheit; they were insoluble in water; they could be injected into timber, in quantity exceeding the maximum which any engineer had as yet required. Would the other, or left-hand part of the group, taken by themselves, preserve timber? Much less perfectly, as they were more volatile. Would a still further fractioning to the left, if it were practicable, ensure a better result? Not so, but a worse one still; for the lightest oils, which contained the greatest portion of the tar-acids, were, like the tar-acids themselves, the most volatile portions of all.

The Author trusted that he had made clear his reasons for specially objecting to large percentages of tar-acids. Take an honest heavy creosote, free from adulteration, free from mutilation, containing, say, 5 per cent. of tar-acids. If this sample were refused because it did not contain 8 or 10 per cent., the tar-distiller was induced to remove a large portion of the heavier constituents of the bodies to the right hand of the scale, in order to make the proportion of tar-acids larger in the portion remaining. He believed that those heavier portions were the best. He thought that, provided the oils were sufficiently fluid at the temperature at which they were injected, there should be no restriction as to maximum specific gravity or maximum boiling-point. If larger and stronger doses of germicides were desired, it would be far better to put them into the wood in the shape of corrosive sublimate or sulphate of copper, in addition to the heavy oils. This could be done by a double process of preparation, with respect to which he had been lately experimenting.

Timber preserved by antiseptic treatment was an engineering

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material competing with other materials, both as to price and durability. Members of the Institution would appreciate the endeavours of the Author to emancipate an important industry from the effects of any theories which, themselves unproven, might stand in the way of improvement, either as to diminished cost or increased efficiency. Mr. Boulton.

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13 May, 1884.

Sir J. W. BAZALGETTE, C.B., President,
in the Chair.

The discussion upon the Paper on "The Antiseptic Treatment of Timber," by Mr. Boulton, occupied the evening.

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20 May, 1884.

SIR J. W. BAZALGETTE, C.B., President,
in the Chair.

(*Paper No. 1972.*)

"On the Passage of Upland-Water through a Tidal Estuary."

By R. W. PEREGRINE BIRCH, M. Inst. C.E.

IN this Paper a description is given of a method, put forward by the Author, to ascertain the rate of progress of the sewage discharged at Crossness and at Barking in its journey out to sea. The results of the calculations, hereafter explained, were laid before the Royal Commission, on "Metropolitan Sewage Discharge" who have since reported that they "throw quite a new light upon the distribution of the sewage." The Author believes it is a new way of dealing with an important question, and that it may, therefore, be of interest to the Institution of Civil Engineers.

It is now well known that this problem cannot be dealt with satisfactorily by means of float-experiments; and the Author submits that its only true solution lies in the accurate measurement and localization of the sea-water and fresh-water contained in the river, considered together with the records of the upland-flow contributing to the latter.

If it were not for the incoming of sea-water the time occupied by the sewage-polluted Thames water at Barking in travelling to any lower point (say Gravesend) would be exactly the same as the time required by the Thames, with its tributaries and sewage, to fill the channel between Barking and that point.

But the effect of the salt-water is to occupy part of the channel, and by diminishing the space available for fresh-water, to reduce the time required for the fresh-water to fill that space and pass through it.

By a complete set of salt tests made at regular distances in the length of the river, and at fixed tidal periods, it is a simple matter

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to ascertain with great nicety to what extent any section of the river is occupied by sea-water, and consequently what space is left for sewage-polluted river-water. The time occupied by the journey of the upland-water will be the time required to fill the latter space.

When the problem had to be dealt with, about the end of the year 1882, it was found that the available information, which was not so ample as the Author could have wished, consisted of analyses of samples of water from ten points in the river between Teddington and Southend, taken at high- as well as at low-water, at each point on three different days, namely, the 14th and 22nd of September, and on the 30th of November.

Each result may be held to represent the average composition, at the moment referred to, of the water at the cross-section in which it was taken, as it was obtained from an average of numerous samples at different depths and at various distances from either shore. These samples were taken upon the crest and trough of the tidal wave, and therefore not simultaneously as they should have been for this purpose.

The best, however, had to be made of the materials at hand, and this the Author thought would be done with the least risk of error by dealing with the water in the river at the moments of high- and low-water at Southend, for at these two moments the volume is at its maximum and minimum respectively, and all adjustment is avoided at the lower end, where, the cross-section being greatest, error would be most important.

As high-water and low-water occur earlier at Southend than at each of the other points higher up the river, it was necessary, before using the results of the analyses of the upper samples, to reduce the saltness of those taken at high-water in proportion to the intervals between high-water at Southend and the times when the respective samples were taken, and to perform the opposite adjustment with respect to the low-water samples.

The extent of this modification, which would of course be avoided in future cases, is shown upon the annexed Table. The first two columns of figures represent the numbers of grains of chlorine in 100,000 grains of water found by analysis in samples taken at high-water and at low-water at each place, and the third and fourth columns represent the parts per 100,000 of chlorine in the water at these places at the time of high-water and of low-water at Southend, these being arrived at by assuming the saltness to increase and decrease uniformly throughout the rise and fall of the tide.

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CHLORINE in 100,000 PARTS.

—	At High-Water.	At Low-Water.	At Southend.	
			High-Water.	Low-Water.
		September 14th, 1882.		
Teddington	1·7	1·7	1·7	1·7
Chiswick	4·7	1·9	4·0	2·6
St. Paul's Pier	210·7	4·1	161·0	72·0
Deptford	438·0	49·0	354·0	162·0
North Woolwich	671·0	180·0	581·0	303·0
Barking	745·0	319·0	673·0	420·0
Crossness	918·0	470·0	847·0	570·0
Erith	1,031·0	530·0	964·0	628·0
Gravesend	1,502·0	1,058·0	1,485·0	1,093·0
Southend	1,931·0	1,765·0	1,931·0	1,765·0
		September 22nd, 1882.		
Teddington	1·7	1·7	1·70	1·70
Chiswick	1·9	1·85	1·89	1·88
St. Paul's Pier	89·0	2·4	66·0	25·0
Deptford	311·0	28·8	253·0	89·0
North Woolwich	581·0	162·0	519·0	233·0
Barking	638·0	280·0	592·0	334·0
Crossness	754·0	440·0	719·0	481·0
Erith	886·0	555·0	860·0	588·0
Gravesend	1,352·0	1,062·0	1,344·0	1,079·0
Southend	1,891·0	1,816·0	1,891·0	1,816·0
		November 30th, 1882.		
Teddington	1·7	1·7	1·7	1·7
Chiswick	1·7	1·7	1·7	1·7
St. Paul's Pier	2·8	1·9	2·5	2·0
Deptford	20·0	1·8	16·0	7·0
North Woolwich	118·0	3·1	98·0	29·0
Barking	152·0	5·0	128·8	35·0
Crossness	276·0	18·7	241·0	65·0
Erith	314·0	83·7	291·0	116·0
Gravesend		No sample taken.		
Southend	1,785·0	1,522·5	1,785·0	1,522·5

In Figs. 1, 3 and 5, Plate 8, the half-capacity of the river at high-water is shown by the space between the centre line and the outside upper trumpet-mouthed line, and the half-capacity of the river at low-water by the space between the centre line and the lower trumpet-mouthed hard line. In the same manner the spaces between the centre line and the black lines above and below it, show the amount of fresh water in the river at high- and low-water respectively. The vertical ordinates to these lines represent, not the half-width of river, but half the cross-sectional area, measured

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on the cross-sectional scale. The mean cross-sectional area is shown by dotted lines. The white space along the centre of the Figs. represents the average quantity of fresh-water in the river during the tide referred to in each case.

These quantities have been arrived at by assuming the sea-water to contain 1,961 grains of chlorine in 100,000 parts, upland-water 1·7 grain of chlorine in 100,000 parts; and that 26,000,000 cubic feet a day of London sewage enter the river with 10 grains of chlorine in 100,000 parts. The daily quantity of upland-water having been ascertained during, and for some weeks previous to, the carrying out of the observations, it is easy to ascertain, first the amount of chlorine in the sewage-polluted upland-water, and from that the proportion in which this sewage-polluted upland-water must have been mixed with sea-water to produce the degree of saltness found in any sample of water taken from the river.

It was ascertained that in September the sewage-polluted upland-water contained about 2·75 grains of chlorine in 100,000 parts, and in November about 1·9 grain. In September, therefore, the proportion in which any cross-section of the river would be occupied by sewage-polluted upland-water $= \dfrac{1961 - c}{1961 - 2 \cdot 75}$, where $c =$ the number of grains of chlorine in 100,000 parts found in the water of that part of the river. In November the process would be varied by substituting for 2·75 in the denominator of this fraction the 1·9 above mentioned. This was done, and by dividing the cross-sectional areas in the proportion so ascertained, the results shown upon the diagrams were arrived at. Contrary to what might have been expected, the fresh-water columns below London at high-water and low-water differ but little in volume, which makes the mean of the two extremely near the average column during the whole tide. It will be noticed that between Erith and Southend the form of the river is shown by a much larger number of cross-sections than that of the points at which samples were taken in the same length. The division of the intermediate cross-sections into sea- and polluted upland-water has been done by means of interpolating diagrams, Figs. 2, 4, and 6. On November 30th, this has been done for all the cross-sections between Erith and Southend, owing to no sample of water being taken at Gravesend on that day.

Of course the effect of this division of the river into upland-water and sea-water is only to show the relative proportions of each at various points in the river's length. The fact that the

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upland-water is mixed with the sea-water, instead of being collected at the centre of the channel, as shown on the diagrams, makes no difference so far as calculations as to progress of the upland-water through the estuary are concerned; for the progress is inversely proportional to the cross-sectional area of the space occupied by the upland-water, whether this water pass away to the sea as a concentrated column, or as myriads of infinitely small streaks equal in the aggregate to such a column. Having established the volume of the fresh-water column, the period occupied by the foremost water in it, in travelling from Barking to Southend, is arrived at by the following process, namely, by first ascertaining how many days' upland-water, counting back from the day to which the diagram refers, there is in the river between Teddington and Barking, and then by counting back from the earliest day that has contributed to the water above Barking, the number of days that must have contributed upland-water sufficient to form that part of the column between Barking and Southend.

The average daily flows of upland-water and of sewage contributing to the fresh-water columns shown on the diagrams were as follow:—

	Cubic feet.
14th September	172,364,082
22nd „	176,528,509
30th November	848,803,496

Thus, on the 14th of September, 1882, the mean column of upland-water between Teddington and Barking was nearly equal to that entering that part of the river during the thirteen previous days (Fig. 7); and the column between Barking and Southend contained nearly as much as passed over Teddington weir during the thirty-two days preceding those thirteen, namely, 1st August to 1st September inclusive, together with such increment as the Teddington water of these thirty-two days acquired up to the 14th of September. The Barking sewage of the 14th of September must have mixed with the water that passed over Teddington weir on the 1st of September, and that of the 14th of August with the Teddington water of the 1st of August. So, as will be seen on the diagram, Fig. 7, the sewage discharged at Barking on the 14th of August was off Southend on the 14th of September.

Fig. 7 shows how the water of to-day is pushed along the river by that of to-morrow; but by thus dividing the column into daily flows by means of vertical lines, each day's flow is made to occupy a portion of the river only a mile or two long. It is obvious,

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however, that this is incorrect, for while a day's fresh-water is entering any tidal portion of the river, the water occupying any given cross-section must have travelled something like 10 miles down the river and back again; so that each day's supply of fresh-water must occupy a part of the river some 10 miles in length; and although the arrangement of vertical lines serves to show how fast the water is made by displacement to pass out of the river, an oblique arrangement, as indicated in Fig. 8, would show more correctly how one day's fresh-water overlaps longitudinally those of previous days.

On the 14th of September, Figs. 1 and 2, the spring-tides were at their highest. On the 22nd of September, Figs. 3 and 4, the neaps were at their lowest; so that the mean between corresponding figures in the diagrams of these two days may be taken as average figures for the whole moon.

On the 22nd of September the quantity of fresh-water between Barking and Teddington was rather more than what had entered that part of the river during the previous thirteen days; and the column between Barking and Southend contained rather more than passed over Teddington weir during the thirty-three days preceding those thirteen, namely, from the 8th of August to the 9th of September inclusive, together with the increment acquired by the Teddington water of those thirty-three days up to the 22nd of September. The London sewage in the river between Barking and Southend was that which had been discharged between the 21st of August and the 22nd of September inclusive. The diagram of the 22nd of September is therefore a record of the sewage that left Barking on the 21st of August, being off Southend thirty-three days later. From thirty-two to thirty-three days may be taken as the average time required for sewage discharged at Barking in August, with such a season as that of the year 1882, to reach Southend.

Figs. 5 and 6 show the condition of the river, the tides being half-way between springs and neaps, on the 30th of November, after a period of considerable flood. There was then a quantity of upland-water between Barking and Teddington equal to the three previous days' flow of the Upper Thames and the tributaries joining it above Barking; and between Barking and Southend there was nearly as much upland-water as came over Teddington weir during the twelve preceding days, from the 16th to the 27th of November inclusive, together with the increment acquired by the Teddington water of those twelve days up to the 30th of November; and the Barking sewage in that part of the

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river must have been what was discharged between the 19th and 30th of November. Fig. 5, therefore, records the fact that sewage discharged at Barking on the 19th of November was by a heavy flood of upland-water carried down to Southend in twelve days.

Although, as appears from the diagrams, a heavy flood of upland-water reduces the saltness of all the water in the estuary, it may here be mentioned that, within certain limits, the quantity of sea-water coming up the river actually increases with the quantity of fresh-water coming down. This will be seen on comparing the quantity of sea-water found on the 30th of November to have been brought up by twelve days' upland-flow with the quantity found in September due to thirty-two and a half days' upland flow. In November the total sea-water between Barking and Southend would be 15,739,986,102 cubic feet, which divided by 12 gives a daily inflow from the sea of 1,311,665,508 cubic feet; whereas in September the mean volume of sea-water between Barking and Southend is 20,623,815,567 cubic feet, which divided by 32½ gives a daily inflow from the sea of 634,578,940 cubic feet. Thus, in November, when the upland-flow was nearly five times as great as that of September, the daily inflow of fresh sea-water was more than twice as great. This is very interesting, because it has hitherto been supposed that the exchange of river- and sea-water is not a very large factor in tidal action.

Although the large volume of sea-water entering a river acts in a very important degree in removing dissolved impurities towards the ocean, and in a minor degree in carrying the same impurities up the river, the Author is satisfied that it has no mechanical effect upon material suspended in the water, for the action of the salt-water is simply one of circulation, which does not affect the mean outward current of the river.

Analyses show that the quantity of sea-water reaching Chiswick was never more than about one hundred and fiftieth part of that reaching Barking, and it is known that the water at Barking never contained more than about one-eighth part of its volume of sewage.

It follows then that not more than one twelve-hundredth part of the river at Chiswick could consist of water which had passed out of the Barking or Crossness outfalls.

It has been shown that the sea-water, which plays such an important part in driving the upland-water out to sea, has no such effect upon floating or suspended matter. It may, therefore, be worth while to mention one fact bearing upon the behaviour of the suspended matter in the river, namely, that in certain parts of

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the river the flood-tide is at springs considerably faster than the ebb. For instance, at Barking, when the Author had an opportunity of making a comparison, it was found that although the volume of water passing on the ebb was only 5½ per cent. more than had passed up with the preceding flood, the time occupied by the downward flow was nearly 30 per cent. longer. This greater velocity might, of course, remove substances upwards from the bottom of the channel which the previous ebb had failed to move downwards.

This fact no doubt accounts in some measure for the anomalous results obtained from float experiments, because floats travelling on the flood-tide at a higher velocity than on the ebb are less affected by the many outside and lateral influences which must operate upon them in any river.

The general effect of the foregoing calculations is to show that owing to the greater specific gravity of sea-water and its tendency to diffusion, the exchange of river-water and sea-water takes place much more quickly than is commonly supposed, so that the upland-water passes even more rapidly through the estuary at Southend than at Barking, where the cross-sectional area is not one-twelfth the size.

The Paper is accompanied by several diagrams, from which Plate 8 has been prepared.

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Discussion.

Mr. H. Law. Mr. H. LAW did not propose to say anything about the rather remarkable theory which the Author had laid down, that the motion or the velocity of water passing through a river would be accelerated by partially filling that river with other water. That was hardly a proposition which would commend itself to engineers. He wished to make a few observations upon the practical use which had been made of that theory by the Author and by other members of the Institution before the Royal Commission on Sewage Discharge, to determine the quantity of sewage which existed in any part of the river. They first took a series of transverse sections of the river throughout its whole length sufficient to enable them to compute its capacity; that in itself was rather a gigantic task. They then proceeded to obtain what the Author called "a complete set" of samples of water. Of course a "complete set" was a very vague term, and to those engineers who knew that if they took samples of water in the Thames within a few minutes and within a few hundred feet of each other they would differ to an extent of 36 per cent., it seemed rather remarkable to accept as a "complete set" two samples taken at Erith and two samples taken at Southend, a distance of 27 miles apart, which were considered sufficient to determine the mean composition of the water in that 27 miles of river. The next quantity obtained was still more difficult of determination, and that was the relative quantities of sewage and water in a given section of the river at a given time. The assumption made was that the sewage entered by a continuous flow, although it was known that in every twelve hours the flow was for four hours and intermitted for eight hours. But with regard to the land-water a more remarkable assumption was made. One of the gentlemen who used that method stated that, owing to what he termed the "theory of impulse" or the "theory of propulsion," and what another gentleman called the "law of continuity," the same quantity and the same quality of water would, one gentleman said, "instantaneously," and the other "in the course of a tide," find its way through every section of the river to its discharge at Southend. Acting upon that law of continuity, they determined the quantity of upland-water at Barking at any given moment to be the same as that flowing over Teddington weir at that moment.

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Sir J. W. BAZALGETTE, C.B., President, said he would submit that it was desirable in the discussion of that Paper to make no reference to any individuals not present or to discussions which might have taken place elsewhere, but to discuss the Paper itself purely from a scientific point of view. Sir J. W. Bazalgette.

Mr. LAW said he was under the impression that he was doing that, but of course he bowed to the ruling of the Chair and sat down. Mr. H. Law.

Mr. BALDWIN LATHAM said that, having been entrusted by the Corporation of London with the conduct of the observations to which attention had been drawn in the Paper, he ought to mention the fact that the results of the inquiry were not based upon those five tidal stations which alone had been referred to by the Author. Through the courtesy of the President he had been supplied with the result of the observations from four tidal stations which had been erected by the Metropolitan Board of Works, and in addition, he had started a tidal station at Beckton, so that in all the observations from ten tidal stations had been used in the inquiry instead of five as mentioned in the Paper. He must take exception to the first clause in the Paper, where the Author took credit for the solution of this mixing theory. Mr. Latham had arranged every one of the observations, subsequently carried out, at least a month before the Author was engaged in the inquiry; before the end of June 1882 it had been determined what should be done in the investigation, the object of which was to ascertain the rate of progress of the sewage out of the river, and also the extent to which sewage was brought up the river by tidal action. In carrying out the investigation, it became necessary to make a complete survey of the river from Southend to Teddington, to determine its sectional area and capacity at all periods of tidal flow. This part of the work was entrusted to Mr. Mansergh, M. Inst. C.E., and to Mr. Charles J. More, M. Inst. C.E. To find the horizontal range of the tides, the float observations were undertaken, and placed under the care of the Author of the Paper, the vertical range of the tides being recorded at ten stations in the course of the river. The Thames at Teddington, and every tributary down to Southend, was gauged, so as to give the volume which produced the displacement of the column of fresh-water. In the course of the investigation he had also to acknowledge the valuable assistance of Professor W. C. Unwin, M. Inst. C.E. In order to gauge the capacity of the fresh-water channel in the tidal way of the Thames, and also to determine the volume of sea-water and sewage transferred up stream by Mr. B. Latham.

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Mr. B. Latham. tidal action, he ordered a series of samples of water to be drawn in different parts of the river, which by ascertaining the amount of chlorine in them, would at once determine the relative proportion of the channel occupied by sea-water, by sewage, and by fresh-water. These samples were drawn in accordance with written instructions prepared by himself, which distinctly stated that the object was to define the proportion of the admixture of upland and of tidal water. The use of chlorine in determining the relative volume in which waters might be mixed was nothing new to him. Thirteen years ago he had mentioned the fact[1] that the Rivers Pollution Commissioners had erred in their estimate of the degree of purification of sewage, as indicated by the relative amount of chlorine in sewage proper and in effluent water, and which showed the different volumes of sewage to effluent to be dealt with. It appeared that the Author had not even now a clear idea of the cause why upland-water went out of the river more quickly than was due to the whole displacement of the water in the channel; he confounded cause with effect, for he said it was due to the channel being partly occupied by salt-water and to the space available for fresh-water being diminished. The real cause, however, of the rapid progress out to sea was the diurnal emptying of the tidal channel, and not its being choked with salt-water. He differed from the Author as to when the chlorine samples ought to have been taken, and considered that the times at which he ordered the samples to be taken, at high-water and at low-water throughout the river, were better periods than those now suggested. He was not going to dispute the fact that the volume of fresh-water could not be measured by observations taken at simultaneous times at high- and at low-water at Southend, and so the total volume of the fresh-water could be accurately measured and the time of its displacement determined, and that the gaugings of the upland-water would show the number of days of fresh-water stored in the river; but what had to be investigated was something beyond this, viz., the transference of sea-water up stream. Now mixing-action took place in both directions in the river, as the upland-water flowed down it flowed into what had been sea-water, and as sea-water flowed up, it passed into the fresh-water. Upland-water flowed out between high-water and low-water in every part of the river, and sea or tidal-water flowed up the river between low-water and high-water. The Author appeared to have overlooked the fact

[1] Minutes of Proceedings Inst. C.E., vol. xxxii., p. 397.

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Mr. B. Latham.

that the progress of upland-water could be determined by simply ascertaining the size of the channel through which the fresh-water flowed out, so that the relative size of the channel occupied respectively at high and at low-water by sea-water and fresh-water being ascertained, a mean between them would give approximately the size of the fresh-water channel throughout the river. Knowing the volume of fresh-water entering it on any day, it was an easy matter to determine the rate of progress seaward. In the method advocated and adopted by the Author, on the 14th and 22nd of September, the proportion of water coming into the river had to be estimated over a long period during which there were no gaugings, as these were only commenced on the 7th of September, and he went back to the 4th of August. If the samples of chlorine had been collected, as suggested by the Author, the amount of sea-water transferred up the river could not have been determined by the same samples, as at the time of high-water at Southend the water in the upper part of the river had not arrived at the low-water period; for while the tide had been flowing up the river for six hours at Southend, for all that period and somewhat more, it would be flowing down in the upper part of the river; so that, as the tests were taken, it was clearly shown that at high-water on the 14th of September, 1882, sea-water was found at Chiswick; but if the suggestion of the Author had been acted on, this discovery would never have been made. Mixing-action was not finished until the tidal flow in the river was complete, and therefore he ordered the samples to be taken at the time specified. It would have been better if he could have had a larger number of samples, but it was not an easy thing to draw samples properly at any other time than at high- or low-water, owing to the unequal period of flow of the tide in every part of the river. With regard to the float-observations, the Author now stated that they were of no value for the purpose of ascertaining the rate of progress of the upland-water out of the river. He appeared to have been labouring, until quite recently, under the idea that the float-observations were intended to show the rate of progress of upland-water out of the river. Now the float-observations were never undertaken with any such object. In 1851 the engineers of the Commissioners of Sewers of the Metropolis had some float-observations made in order to show that there was a certain progress down the river, and this was assumed to be the rate at which sewage and upland-water would pass out of the river. In the reports he drew up for the information of those engaged in the recent inquiry, he pointed out the great error of

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Mr. B. Latham. that conclusion, and mentioned the fact that in all probability the rapid progress down the river of those floats was in a great measure due to the fact that the greater portion of the swims occurred when the tides were taking off, and when there was a greater tendency for matters to pass down the river.

Before entering on this inquiry he had endeavoured to find out what had been done previously, and he had consulted all the records accessible bearing on the subject, amongst others a report dated the 20th of July, 1858, by Messrs. Bidder, Hawksley, and Bazalgette, in which there was a passage that had reference to float-experiments, showing that they were useless to indicate progress out of the river. In that report it was stated, "As they do not represent the actual paths of the particles of sewage, some of which descend and others ascend much beyond the floats. If this were not the case, saline matter from Sea Reach would not be found at Chelsea." The formula used to determine the relative amount of mixture of sea-water and upland-water with sewage was the ordinary chemical formula

$$x = \frac{a - c}{c - b}, \text{ where}$$

x = the number of volumes of b water mixed with one volume of a water.

a = the amount of chlorine in sea-water, 1,961 in 100,000 parts.

b = the amount of chlorine in river-water, or mixed river-water and sewage, being variable, and dependent on the volume of upland-water in the river. Pure upland-water contains 1·7 part of chlorine in 100,000 parts, ordinary sewage containing 10 parts in 100,000.

c = the parts in 100,000 of chlorine found by the chemists to exist in the mixed waters.

When it was necessary to ascertain the rate of percentage in which the waters were mixed, the formula became

$$x = \frac{100\, a - c}{a - b},$$

x being the percentage of b water contained in the mixed water c.

The correctness of the formula, to which Mr. Latham made no claim, was doubted by one of the chemists. Mr. Latham sub-

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Mr. B. Latham.

sequently received a report from Professor Unwin confirming the correctness of the formula. The Author's formula, $\frac{1961 - c}{1961 - 2 \cdot 75}$, was identical with the formula to which Mr. Latham had referred; but when the Author said that "In September, therefore, the proportion in which any cross-section of the river would be occupied by sewage-polluted upland-water," might be ascertained from it, this was not correct. According to Mr. Latham's calculations, the number 2·75 appeared to be too high, because in the upper parts of the river below Teddington a certain amount of pollution came in, adding to the volume of chlorine. This of course was not due to the pollution which came in lower down the river, and it would be seen in his evidence before the Royal Commission that he had supplied a Table showing the figures that should be used in different parts of the river on the days when the experiments were made. Then, again, it was assumed that the formula was correct for the part of the river below the outfall; it could not be correct for any part of the river above the outfall, for the simple reason that although the river was polluted above the outfall by the sewage brought back by the tidal flow, it only found its way up the river for a certain distance, and was decreasing throughout all that distance. In September 1882 the vanishing-point might be taken at Chiswick; therefore between Chiswick and Barking a different value must necessarily be adopted for the mixed upland-water and sewage from that below Barking; but this the Author had failed to do. The Author stated that the average daily flow of upland-water and sewage contributing to the fresh-water column was as followed:—

		Cubic Feet.
1882.	14th September . . .	172,364,082
	22nd September . . .	176,528,509
	30th November . . .	848,803,496

The gaugings of the Thames and its tributaries, including the volume of water-supply, and therefore including the sewage, was shown by actual measurement to have been—

		Cubic Feet.
1882.	14th September . . .	170,150,400
	22nd September . . .	227,152,800
	30th November . . .	802,254,240

These figures showed considerable discrepancies when compared with those of the Author, which might account for some of the errors into which he had fallen. Mr. Latham could not agree

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Mr. B. Latham. with the remark "It may here be mentioned that, within certain limits, the quantity of sea-water coming up the river actually increases with the quantity of fresh-water coming down." Such a proposition was untenable, as the fresh-water coming down depended solely upon the amount flowing down the river, and could neither be increased nor diminished by the sea-water coming up the river; but the more sea-water that passed up the river and mixed with the fresh-water, the greater the quantity of fresh-water, on an average tide, which would be taken out. It so happened that the two days selected for comparison by the Author, to prove that more sea-water was brought up on the 30th of November than on the 22nd of September, had a very different range of tide. It would be seen from the figures referring to the gaugings, that there was much more fresh-water in the river on the 30th of November than on the 22nd of September, but the Author had lost sight of the state of the tides. The higher the tide the greater the tendency for sea-water to enter the river. On the 30th of November there was at Southend a 14-feet tide, while on the 22nd of September there was an 11-feet tide; yet, in spite of this, on the 30th of November, owing to the large quantity of upland-water in the river, there was only 64 per cent. of sea-water above Southend, while on the 22nd of September there was 75·8 per cent. of sea-water above Southend. The actual quantity of upland-water passing out on the 30th of November was not increased by the quantity of sea-water entering the river; but the amount of sea-water entering the river had been diminished by the volume of fresh-water already in the river. On an average, what passed out of the river every day was the tidal-water that entered it plus the water entering by other sources, such as upland-water, sewage, &c., and as the river was emptied twice every day, it was impossible for there to be, on an average, any accumulation. There was a mixing and a slight storing at low-water all the time the tides were taking off, but these were counterbalanced by the increased discharge all the time the tides were making; so that on the average a volume equivalent to that passed into the river either by tidal or upland flow passed out of the river every day.

Some very interesting results had accrued from these experiments. The total area of the Thames basin down to the mouth at Southend was 5,162 square miles, as arrived at by the Commission presided over by Sir Robert Rawlinson, and above Teddington the area was 3,676 square miles. In the recent experiments the actual area gauged for the fresh-water flow was

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4,878 miles, which left only 284 miles, or an eighteenth part of the whole area which had to be computed. The experiments showed, when compared with those made in August 1851, that there had been a somewhat increased range of the tide in the Thames since that period. They also showed that a deep float, in moving up the river with the tide, had a greater velocity than a shallow surface float; but when coming down the river there was a contrary effect, and he had ascertained that the velocity of the tidal-wave between Southend and Erith, was 3,042 feet per minute on the flood tide, while on the ebb tide it was 2,578 feet. From Erith to Deptford, the velocity of the wave on the flood tide was 2,668 feet per minute, and on the ebb tide 1,420 feet, while from Deptford to Teddington, the velocity of the flood tide was 1,192·5 feet, and that of the ebb tide, 401·7 feet. These figures tended to confirm the conclusion, which was arrived at by a Committee of the British Association in 1837, that the velocity of a tidal-wave in a rectangular channel entirely depended upon the depth of the channel; that was, the velocity was the same which a heavy body would acquire by falling a distance equal to one-half the depth of the channel. Comparing the velocity of the tidal-wave with the actual velocity of the current, from Southend to Deptford the motion of the stream would only pass 12·6 miles in a tide, whereas the tidal-wave itself passed through the whole length of the river, or the distance between Southend and Teddington, which was 62½ miles. If Teddington lock were removed, then the tidal wave would pass through a considerably greater distance; for whenever the River Thames was in flood, the wave itself passed over the lock, although there was no direct back flow at such periods, but the wave was transmitted over, and caused a rise and fall in the waters of the river above the lock. The velocity of the flood-current was 192·2 feet per minute, and on the ebb it was 167·6 feet per minute, while the horizontal range of the tide on the flood was 12·6, and on the ebb 12·64 miles, or almost identical. Mr. B. Latham.

As to the propulsion of water through a tidal estuary, it had been argued, supposing the Thames to be a long trough filled with water, that if a volume of ink were put in at the top, that volume of ink would not flow out at the bottom, but a volume of water equal to the volume of ink would flow out. That was what took place in consequence of the impulse, and was not due to the water itself being transmitted. That impulse obeyed exactly the same law as the tidal wave; it travelled exactly in accordance with that law. If the channel was deep the rate of impulse was very much

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Mr. B Latham. quicker than if the channel was shallow; it displaced the water throughout the whole channel of the river in accordance with the volume which was in on any particular day, although it was not the case that it was the particular particle coming in at the top of the channel which flowed out at the bottom. If the problem was reversed and a number of days were taken for this propulsion to travel upwards or down the river, there ought to be high spring water in the upper part of the river several days after it occurred in the lower part of the river; but high spring tide occurred in the upper part of the river on the same day as in the lower part. With regard to the rate of upland water flowing down the river, he had arrived at a formula by which at any time, things remaining as they were, it could be shown what would be the rate of progress out of the river, so that it would be unnecessary to make any further experiments. It was found that the length of time which it took the water to travel out of the river varied approximately as the seventh root of the fourth power of the quantity of water coming over Teddington lock. The figures, when worked out according to this rule, nearly coincided with the well-known hydraulic formula, and showed conclusively the correctness of the deductions. The following figures showed the actual rate of progress of upland water and sewage down the river from Deptford.

Date.	Flow of Thames at Teddington, Cubic Feet per Minute.	Time taken in Days.		
		H.W.	L.W.	Mean.
September 14th, 1882 . . .	83,327	41·38	40·97	41·17
„ 22nd, 1882 . . .	122,461	34·41	31·96	33·18
November 30th, 1882 . . .	476,345	17·05	13·89	15·47

From the above figures it was found that the length of time taken varied approximately—inversely as the seventh root of the fourth power of the quantity of water coming down—

$$T \text{ varied as } \frac{1}{\sqrt[7]{Q^4}},$$

and if Q, the quantity of water passing Teddington, were expressed

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in cubic feet per minute, T, the time taken in days from Deptford to Southend, would be— Mr. B. Latham.

$$T = \frac{26,890}{\sqrt[7]{Q^4}}.$$

The following Table was worked out from this formula for illustration :—

Date.	Flow of Thames at Teddington, Cubic Feet per Minute.	Time Calculated from Formula, Days.
September 14th, 1882	83,327	41·47
„ 22nd, 1882	122,461	33·28
November 30th, 1882	476,345	15·31
Minimum flow 12 cubic feet per square mile less water supply	35,883	67·11

If the results given by the formula were compared with the figures arrived at from the gaugings, it would be seen that they were identical, and that a general law governed the period of discharge; but if the results given by the Author were compared, it would be seen that they were altogether discordant, and were subject to no general law.

Mr. H. C. BAGGALLAY said the Author stated that the quantity of salt in 100,000 parts was 1,961. The quantity of salt to start with was a most important factor in the case. In a very large river flowing into the sea, where there was not much littoral current, the fresh-water diluted the salt-water to a very great extent for many miles round. On other occasions the same river, with a strong wind blowing along shore, might have all the water moved away, and the next tide of perfectly salt-water might come in. It seemed to him very important to know at what points the salt-water was tested for the amount of salt coming in. Mr. H. C. Baggallay.

Mr. E. A. COWPER did not see in the Paper any statement as to the degree of saltness near the bed of the river and near the top, and he should like to know if it had been ascertained. At the mouth of the River Amazon fresh-water was found 300 miles out at sea. It seemed to him that the salt-water would very likely act to some extent as a wedge, and so get under the fresh-water. He believed that in a deep river the surface of the water Mr. E. A. Cowper.

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Mr. E. A. Cowper. began to rise before the water began to flow, at a point say between fresh-water and salt-water.

Mr. L. F. Vernon-Harcourt. Mr. L. F. Vernon-Harcourt was surprised to see the statement that when there was a large volume of water coming down the river, the inflow of tidal water was also larger, because in that case the water in the river must be raised to a greater height. There was a limited space for the fresh-water and the tidal-water to occupy, and the fact of more fresh-water coming down would necessarily prevent the same amount of tidal-water coming up, because, though the tidal-water was unlimited in quantity, yet it only flowed up to fill the space which was left for it to occupy. If the Author's salt-tests led him to suppose that a double quantity of sea-water entered an estuary when a heavy upland flood was passing down, no reliance could be placed on them, as they led to erroneous and impossible conclusions. The Author stated that the sea-water had no mechanical effect on the materials suspended in the water. Of course in time matter suspended in a tidal river, unless it subsided and was deposited, must by degrees find its way out to sea; but there was a kind of backwards and forwards action, and he could not admit that the sea-water had no mechanical effect, because it must carry the silt along with it. This motion of oscillation was the reason why in tidal rivers the same forms of deltas were not found as in tideless rivers, because the silt was kept in suspension, and was deposited in various parts of the river, and not merely carried down to the mouth and deposited where it met the sea-water. In the same way the Author said further on—"It has been shown that the sea-water, which plays such an important part in driving the upland water out to sea, has no such effect upon floating or suspended matter." Of course it would not have an effect in driving it out to sea, but rather tended to keep it in the river itself. The Author's salt-tests could only indicate the distribution and course of dissolved impurities, and furnished no evidence of the movements of suspended sewage matter, which could only be watched by means of floats. Moreover, these tests must be received with great caution, as they appeared to have already led the Author to erroneous conclusions, and as the proportions of salt-water in an estuary were liable to very complex modifications. Thus a strong wind might either back up the fresher water in the upper part of an estuary, or drive it down, and a sudden change of wind might either drive back the outflowing fresher water, on the turn of the tide, or bring up a greater volume of undiluted salt-water. The chemical test, advocated by the Author for

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indicating the passage of polluted water through an estuary, appeared to be open to as many sources of error as float experiments; and, moreover, it was powerless to deal with impurities in suspension. Mr. L. F. Vernon-Harcourt.

Mr. S. S. ALLEN thought there had been an unnecessary misunderstanding of one passage in the Paper, which he certainly did not read in the light that some gentlemen appeared to have done, namely, as if it was an attempt to make out that even when there was more upland-water in the river and more sea-water in the river that would take place without there being any increase in the bulk of the water. He did not think the Author had at all committed himself to that statement. What he understood him to mean was, not that there was so much water, but that in a given specified time there had been a great amount of water, and in the difference of the velocity of the water flowing down, there really was in a specified time a great amount of water passing through the channel. That was what he took it to mean, and that he thought disposed of the theory that he had tried to show that there could be double as much, and yet it was the same amount as before. With regard to the question of the amount of saltness to be found in a river as a test of the amount of sea-water that came in, it was perfectly fair to take the standard of the sea-water, such as it might be found in the German Ocean, otherwise how could any test be made? He saw no other possible standard that could be taken to test how much sea-water there was in a river except by asking how much salt there was. Mr. S. S. Allen.

Mr. W. J. DIBDIN said he should like to draw attention to the Table in the Paper. Looking at the analyses of samples of river-water which had been taken on the 14th of September, one sample had been taken at St. Paul's Pier, which contained a very large quantity of chlorine. Looking again to the 22nd of September, he saw that the chlorine had fallen very considerably, and on the 30th of November it had reached the normal amount. Were those three samples to be considered as average samples of the river water at that point during the whole year? Was it to be understood that the river-water at St. Paul's Pier during four months of the year contained something over 200 parts of chlorine per 100,000, and in another four months something over 70 parts, and in another four months only 2 or 3 parts? He should like to ask whether these samples were intended to represent the average condition of the river, or whether the analyses which showed such very high results were simply exceptional during one very limited period, or were they intended to represent the whole twelve months, Mr. W. J. Dibdin.

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Mr. W. J. Dibdin. because if they were intended to represent the average of the river water at St. Paul's Pier, he must say he could not agree with them. He had had the opportunity of examining a large number of samples of river-water taken from the neighbourhood of London Bridge, and he must say that only under very exceptional circumstances during a limited period had he ever found anything like the high results tabulated.

Mr. R. W. P. Birch. Mr. R. W. P. BIRCH, in reply, said Mr. Law apparently misunderstood the theory described in the Paper, and had found fault with the way in which the theory was carried out. In the first place, he spoke of one sample having been taken to represent the average quality of the water in the whole cross-section of the river, but as Mr. Latham stated ten samples had been taken. He did not profess that the whole of this work was undertaken by him. His position in the matter was that he had a certain portion of it to superintend, which was at first the float experiments. This, however, soon greatly changed, because he found that the float experiments would teach but little as to the progress of the sewage. He might say that the mode of ascertaining the progress of upland-water through a tidal estuary, whether right or wrong, as adopted by the engineers before the Royal Commission, was his, and his alone. Mr. Latham was probably quite correct in stating that the names of places on the Thames at which the samples should be taken was fixed by him in June, because he no doubt knew that these chlorine tests would give the high-water and low-water composition of the river at each point. But until August, when the Author put this method forward, it had never been promulgated, and though adopted and defended by Mr. Latham in the latter part of the following January, it was not accepted by him at the beginning of that month. The samples were not taken for the purpose to which they were eventually applied, and that was the reason they were not taken at the times at which they should have been for the calculations described in the Paper. He must distinctly deny that Mr. Latham had anything to do with introducing this chemical plan of ascertaining the progress of the upland-water through the estuary as adopted by the engineers advising the Corporation. Mr. Law said the engineers had to deal with the sewage, and had dealt with it wrongly. He had not referred to the distribution of sewage in the Paper, excepting one remark about the small proportion which reached Chiswick, and that remark, he was pleased to find, had not been challenged. The point to which Mr. Vernon-Harcourt had referred required a little explanation. It was stated in the Paper that although the

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river in November was much less salt than it was in September, yet that a greater quantity of sea-water was brought up into the river in November than in September. The reason was obvious—simply because it came in faster. The quantity of water entering depended upon the rate of speed at which it came in. Mr. Latham said the floats were never intended to show the progress of the upland-water out to sea, and had further argued that the samples of water ought to have been taken at high-water in every point in the river. But if it had been known how the samples of water were going to be used, they would have been taken simultaneously. These analyses had been used for the purpose of defining a column of fresh-water through that mass of sea-water. If one sample after another sample up the river were analyzed when the tide was flowing, the proportion of salt already found in previous samples would be present, and therefore, in his opinion, it was useless to make measurements or analyses otherwise than simultaneously. The figures put forward by Mr. Latham were the same as those given in the Paper; they could not be called formulas as they were simply arithmetical truisms. As to 2·75 representing rather a large amount of chlorine in fresh-water, it would have made practically no difference to the size of the column of fresh-water through the estuary, whether 2·75 or 1·75 had been adopted. He had been asked, supposing he had made a mistake in the quantity of chlorine in the sewage, whether that would have made any difference. Now even supposing he had made a mistake of 100 per cent. in the amount of chlorine in the sewage, it would not have made a difference of one-half per mil. He could not agree that if a given volume of fresh-water came into the river at one end, a given volume of fresh-water would go out at the other; that was pretty plainly proved by the diagrams, and by the Tables which Mr. Latham put before the Commission. At some time between the 22nd of September and the 30th of November the rate of upland-water supply must have exceeded the rate of outflow of fresh-water from the river; for while that column of fresh-water was thickening, the rate of outflow was not equal to the rate of the income of fresh-water from above. He thought that contradicted the statement that a given quantity of upland-water flowing into the river propelled the same quantity out of the river. Mr. Latham had put down the number of days which he calculated the sewage would take to go out of the river in September, and he made this a larger number than Mr. Birch thought correct. The number of days he arrived at was taken by only considering one day's flow over Teddington weir, as if the quantity of water which flowed over

Mr. R. W. P. Birch.

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Mr. R. W. P. Birch.

Teddington weir on the day which the diagram referred to was the quantity that should be used in arriving at the number of days' flow making up the column found in the estuary. That manifestly was not the case. If on a certain day a column of water were found equal to thirty or forty days' flow, it must have been produced by the thirty or forty days' flow occurring before that day, and therefore the day's flow at Teddington for that particular date had no bearing upon the case, or only to the extent of about 3 per cent. This reduced the formula

$$T = \frac{26,890}{\sqrt[7]{Q^4}}$$

to an absurdity. Mr. Baggallay asked whether any notice had been taken of the wind blowing at the time that these analyses were made, and the degree of saltness found in the river. The proportion of salt-water found in the river might depend upon a number of conditions. It might depend upon inequalities in the river, on the wind, or upon all sorts of circumstances. The more salt-water that ascended, the smaller was the space left for the fresh-water, and as soon as it was known how much space was left for the fresh-water, it would be known exactly how fast a given supply must travel through that column. Mr. Cowper asked what was the relative saltness on the surface and at a great depth. He was not prepared to say exactly what would be the outcome of all these experiments; they were not made for the purpose of showing the difference between surface water and the lower water, but his opinion, having looked at a great number of samples, was that there was very little difference. He had found a great many samples at the surface more salt than the samples below, and *vice versâ*, and in many cases the saltness was equally distributed throughout. There was one point on which Mr. Vernon-Harcourt had misunderstood him respecting the effect of the sea-water upon the suspended matter. He knew that the oscillation and general flow of the river had an important influence upon suspended matter, but the penetration of the salt-water into the fresh, which was simply a process of circulation, had no effect upon the suspended matter. The samples taken at St. Paul's Pier were from three or four different points in the breadth of the river, and at two depths, on three different days; he could not say that they referred to any other days, or could be used for any other purpose except as representing the analysis of the water on those particular days.

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Correspondence.

Dr. J. HOPKINSON observed that the Author had clearly shown that in the case of the Thames, the upland water and the sea-water were largely mixed by every ebb and flow of the tide. Suppose that an estuary were straight and of uniform depth, and were free from obstructions, there would be little tendency to such mixing; there would be a pretty rapid change from sea-water to fresh-water, and the rising tide would simply back up the fresh-water. The average rate at which the fresh-water would find its way through the estuary to the sea would be little affected by the ebb and flow of the tide. Some admixture would occur from viscosity and friction, but it would be small compared with what was observed in the Thames. In estuaries, as they actually were, the mixture occurred by the sea-water at the flood running up a part of the section of the channel, past a portion of the water in the channel, pushing it aside as well as, or instead of, pushing it back. This result was in large measure caused no doubt by obstacles projecting from, or recesses projecting into, the banks; but it was interesting to note that it might occur, even though the banks were straight and the section of the channel uniform, provided the depth were not the same across a section; this, too, quite independent of friction or viscosity. The velocity of a wave, such as the tide wave, the length of which was great in comparison with the depth of the water, varied as the square root of the depth. Imagine an estuary having a cross-section, such that whilst the major part of the width was 10 feet deep, there was a channel of small width 40 feet deep, the tide wave would be propagated in this channel with a velocity double what it would be in the shallow parts, if these were not supplied from the deeper channel. Consequently the water would be backed up in the channel, but would not be backed up over the shallows. A great mixing of river- and sea-water would result, and would be again effected when the tide ebbed. Thus one cause, but not the only cause, of the mixture of the waters was the unequal depth of different points of the cross-section of the estuary. The Author argued that the water at Chiswick could not be contaminated more than one twelve-hundredth part by the sewage reaching Barking, thus :—"the quantity of sea-water reaching Chiswick was never more than about one-hundred-and-fiftieth part as much as that reaching Barking, and it is known that

Dr. J. Hopkinson.

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Dr. J. Hopkinson. the water at Barking never contained more than about one-eighth part of its volume of sewage;" therefore since the salt and sewage from Barking went up together, there could only be one part of sewage in the twelve hundred parts at Chiswick. To make this argument conclusive, the comparison should be between the salt at Chiswick at high-water and the salt at Barking at low-water; or more strictly accurately the comparison should be between the water at Chiswick when the tide ceased to flow up and the water at Barking when the tide ceased to flow out. The effect of any recess, such as a tidal basin in the banks of an estuary on the mixing of the water was interesting, and might be made the subject of calculation. Such recesses would have the effect of causing the salt-water to show itself further up the estuary than would otherwise be the case; at the same time the upland-water would pass more rapidly to the sea. Any sewage escaping into the estuary would have its course to the sea, or its admixture with the water higher in the estuary, modified by similar causes. The chemical method used by the Author appeared to be well adapted to afford a great deal of accurate information at less trouble than was possible from any direct observations on the flow of the water.

Mr. W. Shelford. Mr. W. Shelford considered that the fact mentioned by the Author at the end of the Paper, "that in certain parts of the river the flood-tide is at springs considerably faster than the ebb," and the conclusion derived from it, that "this greater velocity might, of course, remove substances upwards," ought not to pass unchallenged. The Author had arrived at this result by taking the average velocity of flood and ebb, and if the transporting power of a river depended upon the average velocity he would be perfectly correct, and many important rivers and estuaries would silt up, because the average velocity was commonly greater on the flood than on the ebb. But Mr. Shelford was of opinion that it was the maximum velocity which removed the substances from the bottom of the channel, and that this would generally be found to be greater on the ebb. The contrary was an indication of an inferior tidal canal, and accompanied the accumulation of sand in the upper portions of estuaries.

Mr. R. W. P. Birch. Mr. Birch, in reply to the correspondence, said he had read with much interest the remarks of Dr. Hopkinson, who observed that the recesses or irregularities in the river, and the greater depth at its centre would cause "the salt-water to show itself further up the estuary than would otherwise be the case," and the upland-water to "pass more rapidly to the sea," and that the chemical

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method described in the Paper "appeared to be well adapted to afford a great deal of accurate information, at less trouble than was possible from any direct observations on the flow of the water." This was precisely the view he entertained when he condemned the notion of ascertaining anything about progress by means of floats, and wrote to the other engineers, advising the Corporation that the proper thing to do was, by means of salt-tests, to ascertain the quantity of sea-water that found its way up the river, and so estimate the rate at which the upland-water was passing down. Dr. Hopkinson not only supported this theory, which Mr. Law had called a remarkable one, and "hardly a proposition which would commend itself to engineers," but he also held the view that no matter how the salt-water got up the river, the more found of it in the river the faster must the fresher water be passing down. There was one point, however, to which it would be well to direct attention, that was that in November the daily inflow of sea-water was greater than that of September when the upland flow was so much less. This would not be the case if this inflow of salt-water were mainly due to any other cause than the lesser density of the upland-water. Mr. R. W. P. Birch.

The conclusion had been challenged by Mr. Shelford that the greater velocity found in a flood-tide at Barking than in the preceding ebb would account for substances being carried upwards. Mr. Shelford stated that maximum velocities and not mean velocities removed substances. In reply he might point out that the velocities dealt with were the greatest which occurred during moderate summer weather; and that as the substances to which these enquiries were directed consisted of sewage-matter, the balance of those velocities had considerable bearing on the question, though they might be followed by winter-ebbs, that would not only remove sewage deposit, but also recent deposits of sand.

In further reply to Mr. Latham's remarks, he might state that in August 1882, in order to save the useless expense of the continuous-float experiments with which he had been entrusted, he put before Mr. Latham, in writing, his view of the question as follows: "The time occupied by the sewage- and fresh-water in passing through the tidal reaches of the Thames can be ascertained more accurately by a system of salt-tests throughout the river than by float-experiments, the results of which must always be subject to the question of whether the sewage passes through the basin with the quickest of the stream or stops with the comparatively dead-water at the sides, and if both, in what proportions." This advice was disregarded, and the continuous system

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Mr. R. W. P. Birch.

of float-experiments was commenced in September, at which time these experiments were unquestionably intended to ascertain the rate of progress of the sewage to the sea, or there could have been no object in carrying them out continuously. After the experiments were completed, and it was found—although they had been conducted with the utmost care—that they had not given the information expected, he produced, from the best material he could obtain, the diagrams laid before the Commission, and which had been explained in the Paper.

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May 27, 1884.

SIR J. W. BAZALGETTE, C.B., President, in the Chair.

THE following Associate Members have been transferred to the class of

Members.

ROBERT GERVASE ALFORD.
JOSEPH EMERSON DOWSON.
HENRY FAIJA.
WILLIAM THEODORE FOXLEE.
ALFRED FYSON.
NEIL KENNEDY.
WALTER HALSTED CORTIS STANFORD.
WILLIAM BARTON WORTHINGTON, B. Sc.

The following Candidates have been admitted as

Students.

RAYMOND JOHN BIRT.
WILLIAM COLQUHOUN.
ROBERT PARKER DODD.
WILLIAM AITKEN DUFF.
WILLIAM FARQUHAR.
JOHN MACPHERSON GRANT.
ERNEST ROBERT JOHNSTON.
HARRY TURNER POTTS.
RICHARD PROVIS.
ALFRED ROWLAND.
LOUIS CHARLES DO ROZARIO.

The following Candidates were balloted for and duly elected as

Members.

DAVID WILLIAM BRUNTON.
FRANCIS ELGAR.
THOMAS EVENS.
ROBERT EDMUND FROUDE.
CALVERT BERNARD HOLLAND.
JOHN MUIRHEAD.
ANTONIO AUGUSTO FERNANDES PINHEIRO.
HENRY ENFIELD TAYLOR.

Associate Members.

JOSEPH PHILLIPS BEDSON.
FRANK HOWARD BENNETT.
ALEXANDER SAMUEL BLUM.
THOMAS STANLEY CLEMINSHAW.
CHARLES JOHN PLUMBE COOMBS, B.A., Stud. Inst. C.E.
SELWYN ALFRED CUTLER.
ERNEST FREDERICK DAWSON, Stud. Inst. C.E.
THOMAS DUNCANSON.
SAMUEL TELFORD DUTTON.
JOHN ELSTON.
ALFRED MONTAGUE FOORD, Stud. Inst. C E.
WILLIAM GALLON.
JOÃO CORDEIRO DA GRAÇA.
RICHARD FREDERIC FITZ - EDMUND HAYES.
HERBERT JOHN LANDON, Stud. Inst. C.E.

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Associate Members—continued.

Charles Desborough Man, Stud. Inst. C.E.
Henry James Marten.
Thomas May, Jun.
Arthur Monckton, Stud. Inst. C.E.
Benjamin Arthur Nathan.
William Robinson.
Alfred Richard Sennett, Stud. Inst. C.E.
Henry de Morgan Snell, Stud. Inst. C.E.
Arthur Watson Thomson, B.Sc.
Theodoro Tuffvesson.
James Wallington.

Associate.

Isaac Adolphus Crookenden.

(*Paper No. 2000.*)

"Wood Pavement in the Metropolis."

By George Henry Stayton, Assoc. M. Inst. C.E.

The necessity for stimulating the efforts of those persons who are actively engaged in the construction and maintenance of street carriageway pavements in the Metropolis and large cities, was stenuously urged during the discussions at the Institution in 1879, when the subject was brought forward by Mr. Deacon[1] and by Mr. Howarth.[2] The object of this Paper is to call attention to the various wood-pavement works recently executed in the Metropolis, and to a comparison of the results obtained thereby. Although the Paper may not contain much that is new, the Author ventures to think that the general interest evinced in works which tend to the efficient and economical maintenance of the carriageways of important thoroughfares, and the direct bearing which such works have upon the comfort and convenience of a community, may be sufficient to justify a review of the progress in this system of pavement.

It may not be uninteresting to consider for one moment the extent of the streets of the Metropolis, and the nature of the materials of which the carriageways thereof are formed; and the Author desires to tender his warmest acknowledgments to the President, who in his official capacity as the Chief Engineer to the Metropolitan Board of Works furnished him with valuable data, and to Mr. W. Haywood, M. Inst. C.E., the City Engineer, and to forty-three chief surveyors of parishes and districts of the Metropolis, for

[1] Minutes of Proceedings Inst. C.E., vol. lviii., p. 1. [2] *Ibid.*, p. 31.

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their courtesy in replying to his communications thereon. The information thus obtained has enabled him to present it in the tabulated form which will be found in Table I. in the Appendix, according to which it appears that at the commencement of the present year, the aggregate length of the streets of London amounted to 1,966 miles. Of that length, however, 248 miles are at present "new" streets, inasmuch as they have not been adopted by a local authority; consequently there are 1,718 miles of public streets under the maintenance of the various authorities, the carriageways of which consist of the following materials, viz.:—

	Miles.
Macadam	573
Granite	280
Wood	53
Asphalt	13½
Flints or gravel	798½
Total	1,718

The extent of the vehicular traffic is equally remarkable, the result of inquiries instituted by the Author showing that in the Metropolis alone, at the present time, there are approximately 100,000 horses and 40,000 vehicles, the licensed cabs numbering 10,381, and omnibuses, &c., 2,223, and the estimated value of the horses, harness, and vehicles, amounts to no less than £5,000,000 sterling. Obviously the ordinary wear and tear of these vehicles must in a great measure depend upon the condition of the street carriageways.

No doubt many members of the Institution have a vivid recollection of the extremely unsatisfactory state of those macadamized carriageways in leading West-end thoroughfares, which have given place to wood pavement. It was rarely the case that such roadways were in a good state of repair; on a hot summer day they invariably emitted disagreeable smells and frequently gave off a great amount of dust; and it is scarcely possible to conceive anything more deplorable than the state of such streets whenever the surface became greasy or sloppy after rain. All things considered there was not only undoubted cause for dissatisfaction, but ample justification in the outcry against the former state of things; as, what with damage to horses, harness, vehicles, and pedestrians' clothing, together with the sheer waste of money in laying down broken granite to be ground into mud, an alteration was most necessary.

The efficient condition of street carriageways is essentially a ratepayers' question, and the unprecedented adoption of wood as a

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paving material in substitution of macadam, proves that several of the Metropolitan vestries and other authorities have taken a new departure, and apparently a step in the right direction. In expressing this opinion it will be readily understood that the Author in no way desires to pass over the respective merits of granite, asphalt, or bituminous-concrete pavements, and of roadways formed with broken granite, flints, or gravel, as they are undoubtedly suitable for certain localities, and in many cases are economical as compared with wood. While therefore it is asserted that a properly constructed wood pavement possesses the advantages of noiselessness, surface elasticity, safety, and cleanliness, and is pre-eminently suitable and economical for business and residential thoroughfares having a high traffic-standard, it should not be forgotten that in the case of narrow business streets leading out of main thoroughfares, wood pavement might be unsuitable, as by reason of the unimportance of the vehicular traffic, the blocks would probably decay internally long before they were worn out by the traffic. For such reasons, and from a sanitary point of view, it would appear that asphalt would not only be preferable, but also eminently suitable.

Large sums of money were expended during the early years of wood-pavement revival, in the acquisition of patent rights of doubtful value, in experimenting thereon, and in foolish contracts. These stages have been surmounted, and the result is that street paving in the West-end has been almost revolutionized within a few years. Wood pavement has been termed a "West-end luxury," and in one sense the assertion is perhaps justifiable, inasmuch as not more than 4·38 per cent. of the wood pavement in London is east of the City, or south of the Thames.

Extent and Construction.

The superficial area of wood pavement laid in London during the last ten years has been 980,533 square yards, its length 53½ miles, and the cost of its construction, together with subsidiary works, has probably involved an outlay of £600,000. On reference to the map (Plate 9) showing the portions paved with wood, it will readily be observed that it is now possible to drive through wood-paved main thoroughfares for a distance of several miles; (*e.g.*) wood pavement is practically continuous from London Bridge, the exception being the eastern part of the Strand, to any of the stations between Chelsea and Uxbridge Road on the West London Railway.

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Obviously, much valuable experience and data have thus been gained as to the best mode of construction and maintenance, and as the Author ventures to think that a paper on Wood Pavement would be incomplete unless it embraced every detail, however simple, he will endeavour to discuss the various points which arise, with a view to ascertaining whether wood has practically realized the expectation, that it would prove to be a safe, convenient, and economical material for street carriageway pavements.

The suitability of "wood as a paving material under heavy traffic" was so fully treated by Mr. Howarth in 1879, that the Author thinks it unnecessary to refer in detail to questions which have reference to the proper growth of wood, the cause and effect of wear and tear, and the method adopted for recording the traffic; the object being to describe at length the various points of construction which have hitherto been only partially considered, together with particulars of recent modifications.

Excavation.—The suggestion has been made that macadamized carriageways might be broken up expeditiously with the aid of explosive mixtures, but the Author would hesitate to try it; as, however slight the concussion and vibration might be, there is little doubt that gas- and water-mains and services, especially those which have been in existence for a considerable period, would be injured. Practically there is little variation in the method adopted, the main object being to get the work done as quickly as possible. In preparing for the construction of the wood-pavement works in Chelsea, the method of operation consisted in breaking up the macadamized carriageways by driving steel wedges into and through the consolidated layer of broken granite, commonly called mac, at intervals of a few feet. The surface or crust being thus "started," its removal was effected by prising it upwards in lumps of a square yard or more with stout hand-levers, 6 to 8 feet long, after which it was easily disintegrated. As a rule, a depth of 9 inches of macadam was thus removed, prior to the excavation of some 5 or 6 inches of foundation.

In those instances where the carriageway had previously been paved with granite upon a concrete foundation, as in Oxford Street, it was found unnecessary to disturb the concrete, since by adding about 2 inches thereto, and floating the surface, a satisfactory foundation was obtained, and considerable expenditure avoided.

Levels and contour.—When the width of a street is irregular, and the levels of the footways on either side vary considerably,

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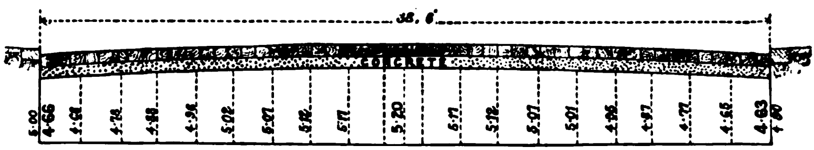
it is sometimes not a little complex to satisfactorily determine the question of level and contour; but when the longitudinal inclination is naturally slight and uniform, the width parallel, and the footways nearly correspond in level, as in Sloane Street, a very simple rule may be observed.

The practice of the Author has been to first determine the level of the crown or vertex of the carriageway to be paved, and next to set out the levels of the channels, by allowing a rise to the crown equivalent to 1 inch in 3 feet ($\frac{1}{36}$) above the mean channel level. By slightly flattening the crown, Fig. 1, it will be observed

FIG. 1.



TRANSVERSE SECTION OF WOOD PAVEMENT IN SLOANE STREET.
Scale $\frac{1}{100}$.

that a contour is obtained which not only renders traffic easy, but is of pleasing appearance, and satisfactory in other points.

Whenever practicable, the longitudinal inclinations of the channels should not exceed 1 in 150, and it is desirable that the minimum depth of kerb exposed at the summit of a channel should be 2½ inches, with a maximum depth of 6½ inches at a gully. By the observance of this rule it necessarily follows, that in a tolerably level street the provision of street gullies becomes an important item, but the extra cost, about 4 per cent., which their construction entails, is amply repaid not only by the convenient and uniform appearance of the carriageway, but in the prompt and effectual removal of rain-water from the surface of the pavement. The Author submits that this is an element of success in the construction of wood pavement which, unfortunately, is too often overlooked.

The longitudinal crown level should be uniformly sustained from street to street whenever practicable, so as to prevent undulations; and it is likewise important that the crown should be extended transversely at all intersections, partly for the sake of appearance, but mainly to obviate the unpleasant effect which is caused by driving over a channel. The neglect of this rule is very apparent upon observing the effect of vehicular traffic over the crossings to Rutland Gate and Princes Gate on the south side of the Kensington High Road.

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Foundation.—It is satisfactory to note that foundations consisting of single or double planks placed upon a bed of sand have been completely discarded, and that the fallacies of the so-called elastic foundation have given place to a more permanent system. It was only necessary, shortly after a fall of rain, to witness the effect of a vehicle being rapidly driven over a pavement which had been laid on the former system for a period of two or three years, to have ocular demonstration of its utter unworthiness. The series of little fountains of dirty water which spurted up in the wheel tracks from the open joints would soon have dispelled the hopes of the most ardent believer in the theory; and the result not only, made it inconvenient for pedestrians, but very soon caused the pavement to go to pieces.

Although lias-lime concrete has been used as a foundation, it may safely be asserted that 90 per cent. of the existing wood pavement is laid upon Portland cement concrete. The latter, properly prepared, is absolutely impervious, and as a solid and sound foundation is essential for a first-class pavement, the Author fails to see that a more suitable material can be substituted. From a variety of causes the strength of the concrete actually used appears to have varied from 5 to 7 parts of Thames ballast to 1 part of Portland cement. In the commencement of the Chelsea works the proportion used was 6 to 1; but it was soon found desirable to provide a quicker-setting concrete, to enable the street to be reopened at the earliest possible moment. The exact proportions, as measured out in boxes, subsequently consisted of 33 cubic feet of ballast to 6·4 cubic feet, 5 bushels, of cement, or about 5¼ to 1.

It is almost superfluous to state that too much care cannot be taken to ensure the use of none but good cement. With this object in view, numerous samples of the cement supplied for the Chelsea works were tested, the average result of 197 tests by Mr. H. Faija, M. Inst. C.E., showing the strength and quality to be:—

Weight per imperial striked bushel	115·45 lbs.
Specific gravity	2·98
Fineness (25 gauge-sieve)	4·18 per cent.
„ (50 „)	26·91 „
Tensile strength per square inch at 7 days . . .	571 lbs.
„ „ „ 28 „ . . .	677 „

The full particulars of the tests are given in the Appendix (Table II.).

The ground having been carefully bottomed up, regulated,

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punned, and when necessary watered, small ridges of concrete, technically called "screeds," were formed to the required levels and contour. The ballast and cement for the concrete were measured out and mixed upon a platform, and twice turned over dry, water being subsequently added by means of a small hose attached to a standpipe. Just sufficient water was used to obtain a fair consistency, and as soon as the materials were well incorporated, the concrete was either wheeled or thrown into place, to a minimum depth of 6 inches. To obtain a perfectly smooth and uniform surface, the concrete was floated and "ruled" transversely to the required contour by means of a curved rule, and in four or five days it became sufficiently hard and ready to receive the wood blocks.

That an excellent foundation was obtained has been frequently ascertained by means of the numerous gas and water trenches which have been made. To break through the concrete necessitates considerable force, and the use of sledge hammers and steel wedges; and specimens prove that it is perfectly sound and good. The entire cost *in situ* averaged 2*s.* 3½*d.* per square yard, an amount which compares favourably with other concretes; and if time were not so important an element in street closing, it might have been executed at a cheaper rate by decreasing the proportion of cement. The cost per square yard is made up of the following items, viz.:—

	s.	*d.*
0·166 cubic yard Thames ballast, at 3*s.* 4*d.*	0	6½
0·74 bushel Portland cement, including extra for facing, at 1*s.* 11*d.*	1	5
Labour in measuring, mixing, wheeling, laying, and ruling	0	4
Total per square yard	2	3½

In the concrete foundation for Fulham Road a considerable quantity of the old broken granite was screened and mixed with Thames ballast, with a view to practically testing the assertion that an equally servicable but cheaper concrete could thus be obtained. A similar system has been somewhat largely adopted in other Metropolitan districts, and notwithstanding that a saving of about 3*d.* per square yard was effected in the Fulham Road pavement, the Author is not encouraged to view the practice favourably, and does not propose to revert to it in future works. He ventures to assert that not only is the old granite of greater value for street repairs in less important thoroughfares, but that consequent upon its dirty condition, the efficacy of the cement is

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somewhat impaired; that the concrete so formed is not so homogeneous as pure ballast concrete, and that it will eventually prove to be less durable than the latter. In support of this view it was recently ascertained by a sample taken up from Fulham Road that such concrete is undoubtedly of inferior quality, and the labour exerted in breaking through it was remarkably small as compared with the former material.

Blocks.—The best form and material for wood-pavement foundation having been ascertained, a question of the utmost importance arises, namely, which of the various kinds of wood available is the most durable and economical? Until this question has been satisfactorily answered it cannot be maintained that the difficulty has been surmounted; in fact, to the absence of reliable information thereon, it is undoubtedly possible to trace the cause of many wood pavements becoming prematurely "worn out" after four or five years' wear. Many theories have been asserted as to the merits of various woods, and a large number of the latter have received a practical test, among them being Baltic and Dantzic fir, pitch pine, spruce, beech, larch, oak, elm, and ash. The shape of the blocks has received no little attention, inasmuch as under various systems they have been cut into rectangular, oblique, hexagonal, octagonal, square, and other forms, and of varying dimensions.

Considerable diversity of practice has also existed with regard to the condition in which wood has been laid, some blocks having been laid in the natural state of the wood, whilst others have either been "dipped" in creosote oil, or "dressed" with pitch, and in a few instances they have been properly creosoted. Within the last six or seven years the greater portion of the wood pavement laid in the Metropolis has consisted of rectangular blocks of Swedish yellow deal, or red deal, or pitch pine, but it cannot be denied that thousands of blocks of an inferior nature have also been laid, after being subjected to the process of "dipping" or "pickling."

Prior to adopting wood pavement in Chelsea, the Author inspected nearly the whole of the various systems then laid in London (February 1879), and gave their respective merits every consideration, the outcome thereof being that a plain and substantial system was considered the most desirable. The blocks found most suitable, and of which there is an abundant supply, were those cut from Swedish yellow deals (Gothenburg thirds), and if blocks cut from close and evenly-grained, well seasoned, and thoroughly bright and sound deals of that description were

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always used, the Author thinks that they would not fail to give satisfaction. In the construction of wood pavement, it is of the greatest importance that constant supervision should be exercised with a view to ensuring the rejection of improper blocks, or blocks which possess even a suspicion of being sappy, knotty, badly cut, or otherwise unsound, or which have been cut out of dead wood, or wood which has been stacked in dock for too long a period. If this system is faithfully carried out, it is doubtful whether there is at present any better wood in the market, of which sufficient quantities can be promptly obtained, and which so satisfactorily stands the wear and tear of traffic, and the changes of atmosphere and climate, than Swedish yellow deal, when laid in its natural state.

The result of heavy traffic upon various kinds of wood unquestionably demonstrates that of hard woods pitch pine takes a high place. The price, however, is considerably in advance of fir, and the irregular sizes of the deals creates much difficulty; but if a satisfactory supply from South America in prime condition could always be relied upon, it would no doubt be largely adopted. A section comprising 756 square yards was laid with pitch-pine blocks in King's Road, four and a half years since, as an experiment, and the ascertained depth of the annual vertical wear of the wood during that period, as will be seen by Table III. in the Appendix, is 0·055 inch only. Experience proves that its abrasive wear is better than yellow deal, and as a rule it dries quicker and is cleaner; and although pitch-pine takes the best position as regards vertical wear, its extreme hardness may be considered a drawback. This is especially noticeable in the case of rapid traffic, when the wheels of vehicles have lost the rolling motion and strike the surface with great force. It is then that the smallness of the elasticity attached to pitch-pine blocks becomes apparent, by a jarring, bumping motion, which is far from agreeable.

Dantzic fir is durable, but would probably be attended with inconvenience and waste in converting the balks into ordinary-sized paving blocks. Neither elm nor oak blocks would withstand the atmospheric changes to which street surfaces are exposed. Larch would probably take a high position as a street-paving material on account of its hardness and durability, but the available supply is apparently too limited to permit its extensive adoption. There is little doubt that American spruce has been laid in London streets under certain conditions, but such wood cannot be regarded as suitable or durable.

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A brief reference has already been made to the preparatory treatment which blocks have received. In many instances they have been subjected to the process of being "dipped" in a mixture of creosote oil and other ingredients, while in a few instances they have been creosoted or mineralized, but at least one-third have been laid in a plain or natural state. The Author has little faith in the ordinary "dipping" process as a means of preserving the wood; and upon severing "dipped" blocks which have been laid for two or three years, it will be found that a mere external discoloration only exists. Indeed it is difficult to ascertain the nature of the merit which the process is supposed to possess, and there may even be truth in the assertion that it is worse than useless, as unfortunately, unscrupulous persons have taken advantage of it as a means of covering up the shortcomings of defective or inferior blocks.

A great deal has been written as to the value of creosoted blocks, and, by way of experiment, a short section upon this system was also laid in King's Road, the blocks creosoted being selected yellow deal. They were subjected to Bethell's patent process, 7 lbs. of hot creosote oil per cubic foot, equal to 10·66 blocks, being injected; and the ascertained depth of annual wear averages 0·139 inch against 0·055 inch for pitch pine, and 0·144 inch for plain yellow deal. The creosoted blocks when taken up for examination were moist internally, and came up easily, whereas the plain blocks and the pitch-pine blocks required considerable force to remove them. The Author has invariably noticed that the creosoted section is less clean than any other, and he certainly doubts the wisdom of a system which is not only 20 per cent. more costly, but to a certain extent closes the fibres of the wood, and tends to produce premature internal decay. When the latter sets up, it will very soon be found that the traffic causes the fibres to spread, which is quickly followed by the complete destruction of the wood.

There can be little doubt that the reputation of wood pavement has seriously suffered on account of the use of unsound and inferior wood. This may be traced to several causes, either the acceptance of extremely low tenders from inexperienced persons, want of sound judgment in selecting the deals, carelessness, insufficient supervision, especially when the work is hurriedly done, or downright neglect. The experience of the Author is, that even with fairly good supervision it is possible for defective blocks to be laid, and it cannot therefore be surprising that unsound wood is used when carelessness, indifference, or neglect is exhibited. As an

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instance of the success of close supervision, the short section of wood pavement at the extreme north end of Sloane Street may be mentioned. The ascertained traffic, which consists in a great measure of carriages and cabs, is equal to 371 tons per yard width per day, or upwards of 100,000 tons per annum; and although the wood has been laid for four and a half years, the blocks have only worn $\frac{3}{8}$-inch, or 0·083 inch per annum, and the surface is in excellent condition. It cannot, therefore, be too strongly urged that street authorities should not only invariably pay a fair price for work, but should provide ample and competent supervision, if they desire to prevent wood pavement from being brought into disrepute.

There is little variation in the dimensions of the blocks, the general size being 9 inches long, 6 inches deep, and 3 inches wide. The lengths have frequently varied from 8 inches to 11 inches, in several instances the depth has varied from 5 inches to 7 inches, but the width, 3 inches, has almost universally been adhered to, it being apparently the best size for foothold, and most convenient to procure. Upon measuring blocks supplied by timber merchants, it will frequently be found that the depth is a trifle short of the specified dimensions, for instance, a 6-inch block seldom exceeds $5\frac{7}{8}$ inch, it being understood to be the custom of the trade to make an allowance for the thickness of the saw-cut. The question has often been raised whether 7-inch blocks on the one hand, or 5-inch on the other, would not be more economical than 6-inch; and although there is very little experience thereon, the subject will be alluded to under the heading of durability.

Laying, Jointing, and Completion.—Great diversity of practice has existed in the mode of laying and jointing, and a great deal of money has been lost in the acquisition of patented inventions. Under some of the latter systems the blocks were laid on boards upon a foundation of sand, in others the blocks were laid upon a layer of asphalt, or upon tarred felt placed upon a concrete foundation. Blocks have been laid in transverse courses, and, under Lloyd's "keyed" system, diagonally. Various modes of jointing have been adopted, technically known as mastic, semi-mastic, cement, lime, or felt, the latter being a close-joint, whilst the former varied from $\frac{1}{4}$ inch to 1 inch in width.

In the Chelsea pavements the dimensions of the blocks were 3 inches by 9 inches by 6 inches, 40·5 being required for each square yard, and they were laid upon the concrete in their natural state, with the fibres vertical, and with intervening spaces $\frac{3}{8}$ inch wide, which were filled with cement grout. The surface of the

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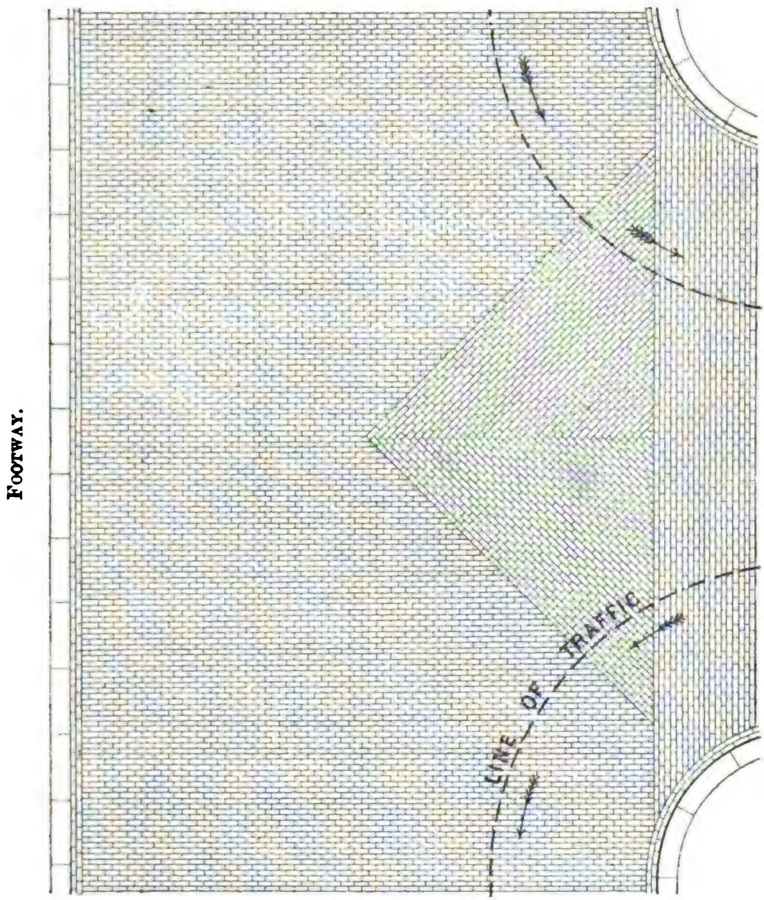
concrete having become hard and smooth, the method of operation consisted in laying two longitudinal courses of blocks next to the kerb to form the channels, and filling in with straight courses transversely, the ends of the blocks being in contact. At the

Fig. 2.



Mode of Blocking at Intersection of Streets.

intersections of streets the courses were laid V shape, so as to ensure the traffic passing over the blocks at an angle of 90°, or as nearly as possible thereto (Fig. 2). In laying the blocks, the joint was kept parallel by means of three cast-iron studs fixed

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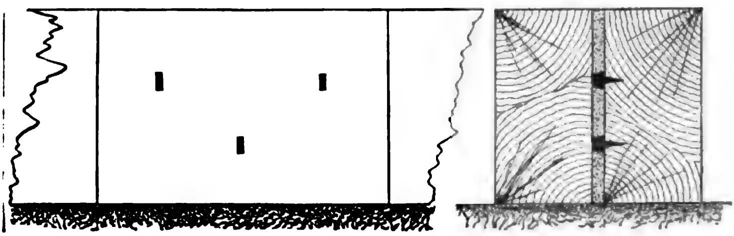
in each block (Figs. 3 and 4), which materially assisted in keeping the pavement firm and steady until the grouting had thoroughly set. By the use of studs instead of wooden strips or laths, it is certain that the blocks are much less liable to become displaced while the

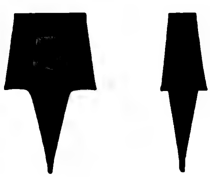
FIG. 3.



MODE OF JOINTING.

work is setting, and in practice a uniform width of joint is more easily secured.

FIG. 4.



FORM OF STUD.
Full size.

The grout was composed of 3 parts of Thames sand to 1 part of Portland cement, the materials being measured in boxes and mixed to a proper consistency, in a large movable grout truck. The grout having been swept out of the truck on to the surface of the wood, was swept backwards and forwards until every joint was properly filled. The prime cost of this work, labour and materials, amounted to 5*d.* per square yard.

Before permitting vehicular traffic to pass over new work, it is desirable to "top-dress" the surface of the wood with a fine gritty material. This is usually done by spreading a thin coating of very small stones, as screened from Thames ballast, sand, or shingle, over the entire surface, and leaving it to be crushed and ground into the fibres of the wood by the traffic, until it has ceased to be gritty. The cost of this work for the Chelsea pavements amounted to 2*d.* per square yard for materials and labour. Whenever practicable all traffic should be excluded from a newly laid pavement for at least a week after completion, but there is an obvious difficulty in the enforcement of this rule, whenever a street is too narrow to allow the works to be carried out in half-widths at a time.

The expansion of wood is a question demanding consideration in carrying out such works. In unprepared blocks this is specially

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necessary, and in proportion to the width of the street so is it desirable to leave a space next the footways, varying from 1 inch to 2 inches in width. The actual condition of the wood and the state of the atmosphere at the time of laying, exercise a material influence upon the width of the margins thus left. Another mode is by omitting to grout the channels for a week or longer period after the other portions have been completed; and another by paving nearly up to the kerb, and afterwards taking out the nearest course so soon as expansion sets up. In any case, it is necessary to temporarily fill up the margin with sand or other suitable material, which can be raked out from time to time until expansion ceases, which generally occurs in the course of twelve to eighteen months from completion. In the Chelsea works it was then found desirable to rake out the temporary filling, and where any space was left, to fill in with cement grout, the surface being carefully pointed in cement. This work effectually renders the channels impervious to water, and tends to prevent premature decay; and was executed at a cost equal to 0·86*d.* per square yard of pavement.

It frequently happens that, notwithstanding those provisions, and whether the blocks are plain or dipped, the outer portions of the footways become displaced during the period of expansion, but subsequent to the above-named period wood pavement generally maintains a fairly constant state. The Author has never observed any contraction in wood pavement except during the severe frost in January 1881, at which time, when 22° of frost were registered, several rather alarming cracks in a longitudinal direction appeared in the Sloane Street pavement, at places where the wood was especially exposed to the severity of the weather. Immediately the frost terminated the cracks appeared to close up naturally, and the pavement assumed its former sound condition.

This plain system of pavement was laid in Sloane Street and King's Road in 1879, and upon closely observing the effect of nearly five years' traffic upon it, the result is eminently satisfactory. The plain type of pavement had previously been adopted by Messrs. Mowlem & Co. in several parts of the Metropolis, with the exception that their joint was wider and was formed of lime grout, and that their form and manner of studding were different, and the Author ventures to assert that it comprises all the essentials of a sound pavement; a quiet and smooth surface for vehicles being provided, and the pavement being sufficiently close-jointed to ensure a safe foothold for horses.

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Experience proves that the cement-joint is reliable, that it adheres to the blocks, effectually resists wet, and does not unduly wear down below the surface of the wood, and thereby allow dirt to accumulate in the joints, neither does it permit displacement of the blocks; the Author therefore feels that he may justly pronounce it successful, and claim for it another advantage as compared with the mastic-joint, viz., the absence of the annoyances which are created by asphalt kettles in streets, during the execution of the works. Upon inspecting the numerous openings which have been made for gas and water services or drainage works, the actual condition of the wood and foundation has invariably proved satisfactory; the surface of the concrete is hard and dry, the joints are sound, and the blocks as a rule present a fairly good surface, and are not found to contain an excessive amount of moisture.

The prime cost of the pavement in King's Road and Sloane Street amounted to 10*s.* 6*d.* per square yard, and the only repairs which have been found necessary, consisted in the removal of some defective blocks during the past twelve months. The blocks were originally 5·87 inches deep, whereas their present average depth measures 5·22 inches in King's Road and 5·60 inches in Sloane Street. The probable life of the blocks may be taken at seven years for King's Road and eight years for Sloane Street. The annual vertical wear of wood is equal to 0·144 inch in King's Road and 0·065 inch in Sloane Street, and if reduced to a traffic standard of 750 tons per yard width daily, the following results are obtained, viz.:—

King's Road . .	0·196 inch.
Sloane Street . .	0·175 „

Several other systems of pavement were laid in King's Road at the same time for the purpose of practically testing their respective merits. In one instance a layer of metallic lava asphalt ½ inch in thickness was laid upon the concrete foundation, the blocks being laid and jointed as already described. Opposite the Royal Military Asylum wall creosoted blocks were adopted, one length being formed with a semi-mastic joint, namely, the lower-half bituminous mastic and the upper lias lime grout; the other being entirely jointed with grout composed of lias lime and sand. The section of pitch pine blocks previously described was also laid at this part, the joint consisting of Portland cement grout. The Author has carefully examined the various

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experimental sections of pavement, the cost of which, together with the ascertained wear and other particulars, are as follows, viz.:—

(*a*) *Plain deal blocks on layer of Asphalt.*—The cost amounted to 12*s.* 4*d.* per square yard; the present depth of the blocks is 5¼ inches; the foundation is in a perfect condition, and the blocks are fairly good. The estimated life of the pavement is seven years, the average annual wear being 0·139 inch.

(*b*) *Creosoted blocks, with mastic joint.*—The cost was 14*s.* 2*d.* per square yard; the present depth of the blocks is 5¼ inches, and the foundation is perfectly sound. The lime grout part of the joint has perished and almost crumbled away, consequently a good deal of dirt has been pressed into the part above the bituminous portion, and the blocks came up very easily. The pavement may last for eight years, the average annual wear being 0·139 inch.

(*c*) *Creosoted blocks, lime joint.*—The cost was 11*s.* 10*d.* per square yard; the blocks are 5⅜ inches deep, and in a fairly good condition. The failure of the lime joint may possibly arise from a chemical action of the creosote; but it certainly has perished, and causes dirt to accumulate. The blocks will probably last eight years, the average annual wear being 0·111 inch.

(*d*) *Pitch-pine blocks.*—This section costs 11*s.* 8*d.* per yard, and the present depth of the blocks is 5⅝ inches. The foundation is dry and sound, and the cement-joint perfectly satisfactory. The repairs to the blocks have been very slight, and they will probably last eight or nine years, the average annual wear being 0·055 inch only.

If reduced to a traffic standard of 750 tons per yard width per day, the figures are: Pavement (*a*) 0·209 inch; (*b*) 0·240 inch; (*c*) 0·204 inch; (*d*) 0·088 inch.

Practically, the plain pitch-pine pavement is cheaper than yellow deal, and the ascertained vertical wear promises admirable results; but it does not appear that either of the other modes is attended with any particular advantage.

Other Pavements.—In 1876, the Improved Wood Pavement Co. laid a short section in King's Road, near the Vestry Hall, in which planks were laid upon the concrete foundation, and "dipped" pitch-pine blocks were used; but in consequence of numerous complaints of the disagreeable rumbling and jarring noise which the rapid passage of vehicles over it caused, it was taken up and relaid without the boards after a period of seventeen months, an additional length being at the same time laid with "dipped" deal blocks. These pavements were subsequently par-

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ticularly unfortunate, inasmuch as the "mastic" joint caused the surface to become uneven and bumpy, and rendered it necessary to execute frequent repairs, a considerable portion being relaid in 1882. Upon examination it transpired that the substance which formed the "mastic" joint had partially melted, presumably from the heat of the sun, and that the material had got underneath the blocks and forced them upwards. In November 1883 the pitch-pine section was finally taken up, and the other portions were again repaired by the Company for the same cause. Like results may be seen in other districts, where a similar joint has been adopted.

The ascertained average depth of the pitch-pine blocks at the time of removal, was $5\frac{3}{8}$ inches, the average annual wear during a period of seven years being 0·089 inch, or if reduced to the traffic standard, 0·119 inch. The deal blocks were measured and found to be 5 inches deep, the ascertained annual wear being 0·157 inch, and according to the traffic standard, 0·195 inch. With additional repairs, the latter may last another year, making their life seven years. The Author further objects to this form of joint, because the melted asphalt adheres so tightly to the surface of the concrete that it is necessary to chip it off before new blocks can be laid, which process destroys the smooth surface of the concrete so considerably, that it necessitates a bedding of sand before new blocks can be properly laid. Further, the bitumen adheres so tightly to the blocks that to well cleanse them for re-use not only involves much labour, but is injurious to them, especially if they have borne two or three years' traffic, and the fibres have begun to spread. In the latter case they are not only unsound, but are also unfit to make neat or satisfactory work.

The Improved Wood Pavement Co., whose experience is probably greater than that of any other company, have laid their system in many of the leading streets, among which may be mentioned, King William Street, Bishopsgate Street, Queen Victoria Street, Whitehall, Bond Street, Park Lane, and Old Brompton Road. In all instances where the patented system had originally been adopted, advantage was taken to modify and simplify it whenever it became necessary to renew the blocks. The company have entirely discontinued to lay a plank in the foundation, and now limit their system to the use of "dipped" blocks, laid with a semi-mastic joint upon a concrete foundation. For the purpose of comparison, the weight of the traffic being known, the following streets are referred to:—

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Ludgate Hill.—Originally laid on boards in November 1873, at a cost of 18*s.* per square yard. The terms of maintenance are, one year free, and fifteen years 1*s.* 6*d.* per square yard per annum. The blocks and plank foundation were taken up and new blocks laid on a concrete foundation and single board, in 1877. The pavement was again taken up and laid with new blocks on the new principle, namely, without the intervening boards, in February 1884, when the blocks were found to average 3 inches deep, their actual life being seven years. The Author saw this pavement taken up, and was surprised to find how easily it was removed; the mastic joint had evidently lost its strength, and the result possibly points to the fact that its efficient durability does not extend beyond a limited period. The annual average wear of the last-mentioned wood was 0·428 inch, and if reduced to the traffic standard, it was equal to 0·259 inch.

Aldersgate Street.—Cost 15*s.* per square yard in September 1874; the maintenance terms being two years free, and fifteen years at 1*s.* per square yard per annum. It was taken up and relaid on a concrete foundation in 1877, the blocks being merely reversed, and laid on lias lime mortar. In March 1884 the blocks were renewed, the average depth then being 3½ inches; but in some parts the wood was only 2 inches thick. The annual wear was equal to 0·263 inch, and the actual life of many of the blocks was no less than nine and a half years. The blocks recently laid are 5 inches deep.

Northumberland Avenue.—Paved in February 1876, at a cost of 15*s.* per square yard, exclusive of the concrete foundation, which had been laid by the Metropolitan Board of Works. It is maintained by the Company at the rate of 13*s.* per square yard for fifteen years. Baltic pine blocks, 6 inches deep, were laid on planks, and the approximate wear is 0·125 inch per annum. The surface is uneven, and shows considerable wear at the upper end, but its life will probably be nine years.

Leadenhall Street.—In July 1876 the western end was paved at a cost of 12*s.* 3*d.* per square yard, with two years' free maintenance, and fifteen years at 1*s.* per square yard per annum. The pavement was taken up, and 5-inch blocks laid in 1879, without the planks. The wood is considerably worn, and the surface is bumpy, probably from the mastic joint. The approximate wear of the wood is 0·200 inch per annum, which, reduced to the traffic standard, is equal to 0·186 inch per annum.

Piccadilly.—An area of over 16,000 square yards was laid in April 1876. In 1880 nearly two-thirds were renewed, and the boards

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taken out, the remainder being done in February 1882. Further repairs have been executed, and the surface shows considerable signs of wear. The Author has been unable to obtain information as to the depth of blocks.

Knightsbridge.—The portion east of Albert Gate was paved in April 1878, the blocks being laid upon a single plank, and concrete foundation. The part west of Wilton Crescent was taken up in September 1883, when the plank was removed, consequently the actual life of the wood was nearly five and a half years. The daily traffic is about 780 tons per yard width, or 250,000 tons per annum.

Parliament Street was paved in December 1880, at a cost of 13*s.* 8*d.* per square yard, and the Company maintained it for three years at an additional charge of 4*d.* per square yard per annum. The foundation is Portland cement concrete, 12 inches thick. The annual wear of the wood is 0·154 inch, and if reduced to the standard, is equal to 0·104 inch.

Oxford Street, opposite Hereford Gardens, was originally laid on boards in November 1874, at a cost of 16*s.* per square yard, with maintenance two years free and thirteen years 1*s.* per square yard per annum. In May 1877 the boards were removed and new blocks laid, but they are now in a very bad condition, and are about to be taken up. Their life will have been seven years.

Henson's patent pavement has been practically tested, having been laid in Fleet Street, Oxford Street, Brompton Road, Euston Road, Uxbridge Road and elsewhere. The theoretical principles of this system, which consists of a cement-concrete foundation, plain deal blocks on a felt bed, a close felt joint, and a dressing or grouting of boiling prepared tar, and the merits of the felt bed and joint were fully described in Mr. Howarth's Paper, and the following particulars of ascertained wear may be useful in considering its merits.

Oxford Street, Princes Street to Marylebone Lane, was laid in November 1875, at a cost of 16*s.* 6*d.* per square yard on existing concrete. The Company offered to maintain it for fifteen years for 10*s.* per square yard, but the Marylebone Vestry arranged to do this work by their own staff. The pavement was repaired in 1879 and following years, the blocks being entirely renewed in September 1883. Yellow-deal blocks, 5 inches deep, were originally laid, and when taken up averaged 3½ inches thick, their actual life being 7·84 years. The annual average wear of wood was therefore 0·191 inch, which, if reduced to the traffic standard already described, gives 0·120 inch.

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Oxford Street, Duke Street to Portman Street, was paved in October 1876, at a cost of 14*s.* per square yard on existing concrete, the maintenance terms offered being 10*s.* per square yard for a period of twelve years. 6-inch blocks were laid, and they were repaired in 1880, 1881, 1882 and 1883, their present average depth being 3·60 inches. The surface of the wood is considerably worn, but upon recently inspecting an opening in the pavement, the foundation and joints were in an excellent condition. The probable life of the blocks is eight years. The average annual wear of the wood is equal to 0·323 inch, and as reduced to the traffic standard 0·255 inch.

Oxford Street, Hereford Gardens to Edgware Road, was paved in December 1875, at a cost of 16*s.* 6*d.* per square yard on existing concrete. The blocks were repaired each year from 1879 to July 1883, when they were renewed. They were originally 6 inches deep, were worn to an average depth of 3½ inches, and had a life of 7·58 years. The probable life of the existing blocks is eight years. The annual average wear of the former wood was 0·329 inch, and as reduced to the traffic standard was equal to 0·250 inch.

Brompton Road.—The eastern half was paved in December 1878, at a cost of 12*s.* 9*d.* per square yard, with a free guarantee for three years. Since then frequent repairs have been executed by the Kensington Vestry. 6-inch blocks were laid, the present average depth of which is 4·94 inches. The surface is worn in places, and is bumpy and somewhat unpleasant to drive over. It is very dirty at the joints. The probable life of the wood is six and a half years, the average annual wear being 0·184 inch or according to the traffic standard 0·236 inch.

Fleet Street.—The western half was laid in September 1877, at a cost of 16*s.* per square yard, the maintenance charge being 17*s.* per square yard for nineteen years. It has been repaired from time to time since 1881, and is now considerably worn and uneven. The probable life of the wood is seven years. The average annual wear of the wood is 0·269 inch, which according to the traffic standard is equal to 0·173 inch.

Leadenhall Street.—In August 1876 the eastern half was paved at a cost of 18*s.* 6*d.* per square yard, the maintenance being two years free and seventeen years at 1*s.* 6*d.* per square yard per annum. The paving has been repaired on several occasions since 1880, and parts are now in a very bad condition, the wood having quite worn through in places. The paving is to be renewed this spring, after a duration of seven and a half years; and, taking the

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average depth of the blocks at 4 inches, the annual wear is equal to 0·264 inch, which reduced to the traffic standard is 0·198 inch.

Euston Road, Cleveland Street to Gower Street, was paved in November 1880, at a cost of 11*s.* 6*d.* per square yard, with three years' free and twelve years' annual maintenance at 8*d.* per square yard. The pavement is in fairly good condition, only trifling repairs having been carried out, notwithstanding that the weight of the traffic per yard width is equal to 700 tons per day.

It must be apparent to any one who has carefully noticed Henson's pavement that there is a minimum of jarring, and consequently a very steady motion in driving over it when it is in good condition; yet experience seems to prove that after a few years' wear it is not in reality cleaner or less dusty than a plain close-jointed pavement, and a reference to Table V. in the Appendix clearly shows that in durability it does not take the highest place.

The system adopted by the Asphaltic Wood Pavement Co. consists in laying a ½-inch layer of asphalt upon the concrete foundation, upon which "dipped" blocks were placed, the lower part of the joint being of asphalt and the upper of Portland cement grout. This pavement has been laid in Fleet Street and other parts of the City, The Strand, Oxford Street, High Holborn, Hatton Garden, Brompton Road, and elsewhere.

Oxford Street, Marylebone Lane to Duke Street, was laid in September 1876 upon an existing concrete foundation, at a cost of 13*s.* 6*d.* per square yard, and offered to be maintained for fifteen years at 12*s.* per square yard. It was repaired in 1878, and each successive year to November 1882, when the blocks were removed, and the pavement relaid upon the plain system with a cement joint. The blocks originally were 6 inches deep, and when removed had worn down to about 3 inches, their actual life being about 6·20 years. The average annual wear of wood was 0·484 inch, which, reduced to the traffic standard, is equal to 0·319 inch. The pavement suddenly broke up and went to pieces at the end of 1882, owing, it is stated, to water getting underneath, and the asphalt breaking up, which was probably caused by the "open joint" of asphalt and lime grout.

The Strand was paved in February 1877, the cost being 13*s.* 6*d.* per square yard, and maintenance undertaken at 1*s.* per square yard for twelve years. 6-inch Baltic red blocks were used, and the pavement lasted till 1882, when it was renewed. The actual life of the wood was a little over five years, but it should be

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observed that the daily traffic is upwards of 1,100 tons per yard width.

Fleet Street.—The eastern portion was paved in July 1877, the cost being 15*s.* per square yard. Considerable repairs have been carried out, but it is much worn, more so than Henson's pavement, and is somewhat bumpy to drive over; this may perhaps be partly accounted for by the gradient being sharp. The average annual wear of the wood is 0·456 inch, which, reduced to the traffic standard, is 0·251 inch.

Regent Street.—The portion between Piccadilly Circus and Vigo Street was paved in September 1880, at a cost of 12*s.* 6*d.* per square yard, on a cement concrete foundation, 12 inches thick, formed of 2 parts of old macadam to 1 part of ballast. 6-inch deal blocks were laid, but they already show considerable signs of wear, in fact they needed repair in 1883. The ascertained annual wear is 0·286 inch, which, reduced to the traffic standard, is equal to 0·384 inch.

Brompton Road.—The eastern part was paved in December 1878, at a cost of 13*s.* 9*d.* per square yard. The blocks have been repaired on several occasions; the surface is in a more uneven condition than Henson's pavement, and the joints are much worn. The life of the blocks may be put at six and a half years. The ascertained annual wear is 0·373 inch, which, reduced to the traffic standard, is equal to 0·431 inch.

The Author fails to observe that the asphalt bed and joint possess the merit claimed for them, and certainly the pavement in Brompton Road, the surface of which became irregular at least two years ago, is in an extremely unsatisfactory state, owing no doubt to the failure of the joint and quality of the wood.

Lloyd's patent "keyed" pavement was laid in Pall Mall in February 1879, and, from the deplorable condition into which it had fallen in December 1883, there can be little doubt that it has proved an utter failure. Unquestionably the work was carelessly executed, as the Author found blocks varying in length from 8 inches to 15 inches, and joints from 1 inch to 2 inches in width; and when it is considered that the blocks were laid diagonally, although the wood used was pitch pine, it is not unreasonable to attribute the failure to the mode of jointing and diagonal form of blocking. The specimen blocks submitted were taken up in December 1883, and they reveal the fact that the so-called "key" was no key whatever, it having entirely failed to hold the blocks together; and considering the irregularity of the width of the joint and the poorness of the material with which it was

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formed, together with the uneven bedding of the blocks, it will be readily understood that the joints soon wore down, and that the blocks became rounded, thereby rendering the pavement uneven and more bumpy to drive over than any other modern system. The pavement originally cost 8*s.* 5*d.* per square yard only, being laid on an existing concrete foundation. When the blocks were removed they were about 4¾ inches deep, but being so much rounded and unevenly worn, it was found that they could not be turned and relaid; consequently deal blocks upon the plain system were substituted. The life of a large area of the pitch-pine "keyed" blocks was therefore less than five years—an extremely unsatisfactory result, especially when it is remembered that the carriageway is fairly wide.

The same system of pavement was laid in the upper part of Regent Street in September 1880, at a cost of 13*s.* 9*d.* per square yard. It was repaired in 1883, and again this year; it already shows considerable wear, and is uneven in places. The blocks are of pitch pine, 6 inches deep, and the ascertained annual wear is 0·214 inch, which, reduced to the traffic standard, is equal to 0·288 inch.

The pavement known as Carey's system was laid in Cannon Street in September 1874, at a cost of 13*s.* 6*d.* per square yard, the maintenance terms being two years free and fifteen years at 1*s.* 6*d.* per square yard per annum. The blocks originally laid were 4 inches wide by 9 inches by 6 inches, and were shaped with alternate convex and concave ends, and laid on a thin bed of ballast, the joint being formed of lime grout. Considerable repairs and renewals have been carried out from to time, and in March 1884 the Author saw several trenches opened near Queen Street, at which places the original blocks had worn to a depth of 3 inches, the surface being extremely uneven, not to say bad. The western section, which was renewed about a year ago, is already uneven, and begins to show signs of wear, and notwithstanding that the wood has considerable durability, yet, owing to the inferior surface of the pavement, the Author would hesitate to class it among successful pavements.

The ligno-mineral pavement was laid throughout Coleman Street, City, in June 1875 at a cost of 13*s.* 6*d.* per square yard. The paving consisted of mineralized pitch-pine blocks, 4 inches deep, with a "mastic" joint, the top portion being lime grout. The pavement having become worn out, owing to open joints and decayed wood, it was taken up in April 1882, when asphalt was substituted. It is extremely probable that in consequence of

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the carriageway being so much in the shade, the wood was specially liable to retain moisture. Fore Street was similarly paved in December 1874, but the wood was replaced by asphalt in July 1883.

Messrs. Mowlem & Co.'s Pavement.—This plain system of paving has been laid in various parts of the Metropolis, particularly in the City, St. Giles, St. Marylebone, St. Pancras, and Kensington. In Princes Street, Cavendish Square, blocks which were laid in September 1874 are still in existence.

Kensington High Street.—In May 1877 a section was laid near the Vestry Hall, at a cost of 14*s.* per square yard, with a three-years' free maintenance. 6-inch blocks were laid in their natural state, with a ½-inch joint of lime grout. The present depth of the blocks is stated to be 3 inches, the annual average wear therefore being 0·440 inch. The surface shows considerable wear, and after rain, water is retained at those points where it has worn below the channel-level. The latter evil is possibly to be attributed to the very slight rounding, 1 inch in 4 feet, to which it was laid. The blocks are to be renewed in October next, when the life of the wood will have been seven and a half years.

Fulham Road, Sydney Street to Arthur Street.—This section was paved in July 1878, at a cost of 14*s.* per square yard, and in other respects was similar to the last-mentioned pavement. The surface is considerably worn, and the form of joint not only retains dirt but tends to round the blocks, the average depth of which is 4⅝ inches, or equal to an annual average wear of wood of 0·242 inch. The pavement will probably be relaid in 1885, when its life will have been seven years.

A large area of "plain" wood pavement has been laid in Kensington by Messrs. Nowell & Robson, who paved Kensington Road, Fulham Road, Uxbridge Road, and High Street, Notting Hill. The last-mentioned street was carried out in December 1878, at a cost of 12*s.* 6*d.* per square yard, with a three-years' free maintenance. The lime joint gave much trouble shortly after the work was completed, and, in places, it may be observed that it has allowed dirt to accumulate. The average wear is equal to 0·218 inch per annum.

In other Metropolitan districts, besides Chelsea, the local authorities have successfully laid a plain system of wood pavement by means of their own staff of workmen, particularly in St. Marylebone and Paddington. The credit of introducing this method is due to the St. Marylebone vestry, whose first work consisted in paving the portion of Oxford Street east of Regent Circus, in

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October 1878. The blocks were laid upon an existing concrete foundation, and the work cost 8*s.* 4½*d.* per square yard, exclusive of the removal of the old stones. The blocks were repaired in 1882, 1883, and in 1884, at an approximate cost of 6*d.* per square yard. Plain yellow-deal blocks, 6 inches deep, were adopted, with a cement joint ½ inch wide; and they have worn to an average depth of 3·30 inches, but in some parts of the street the thickness is 1½ inch only. The surface shows considerable wear, and is uneven in places, the wood being so remarkably thin near the rests that it is a mere crust. The probable life of the wood is six and a half years. The average annual wear is 0·475 inch, and if reduced to the traffic standard it is equal to 0·306 inch. The heavy rate of wear is probably owing to the width of the joint, the Author having taken up a piece of grout ¾ inch thick. This irregularity would have been avoided by the use of iron studs instead of temporary strips or laths. A large area was similarly laid in Edgware Road in October 1880, and at the same cost. The surface is good; the annual wear is 0·198 inch, and if reduced to the traffic standard it amounts to 0·254 inch.

The Paddington vestry have laid 125,232 square yards in various streets. Praed Street was paved in July 1879 with 6-inch plain yellow-deal blocks, at a cost of 10*s.* 7*d.* per yard, and the surface is in a fairly good state. At the eastern end, the blocks have been repaired on several occasions, the present depth of wood in the centre part being 4 inches to 4⅞ inches.

Generally speaking the plain system appears to have given satisfaction, but the mode of jointing with lias-lime grout, or a wider joint than ⅜ inch, cannot be recommended. Upon inspecting the lime-joint after a few years' wear, it may be ascertained that it wears below the wood surface, that dirt accumulates in the joints, and that the blocks have either become rounded or the top edges "burred," to such an extent that the surface has become bumpy. The lime-joint gave trouble when newly laid in Notting Hill in December 1878, as after a sharp frost the grout, so to speak, "spewed" up, the rain filled the joint, and considerable sections of the pavement were literally afloat until the defects were remedied. A system of blocking, which the Author considers objectionable, is that by which the blocks of a new pavement are laid upon fresh unset cement floating, and, as the grouting is proceeded with, the blocks rammed with a "pavior's" rammer, so as to obtain a smooth surface. Under this process there is a probability of the blocks being injured or split, apart from which it is found that when the time arrives for renewing the wood, the

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surface of the concrete contains a series of indentations instead of being smooth and even. The difficulty may of course be surmounted by chipping off the projecting parts and refloating the surface, but the repaving cannot be so expeditiously or economically carried out. The result of the Author's experience and investigation induces him to submit (1) that the surface of the concrete foundation should be perfectly smooth and fully set before the blocking is proceeded with, and (2) that a carefully-made cement-joint $\frac{3}{8}$ inch wide will not only be found simple and water-tight, but will prove as durable as the wood itself.

Cost.—With the exception of a small area, the whole of the wood pavement in Chelsea, about 50,000 square yards, has been laid by the Board's own staff. The estimated cost of the pavements in King's Road and Sloane Street was 11*s.* 3*d.* per square yard,[1] but, as previously stated, the actual cost amounted to 10*s.* 6*d.* per square yard, exclusive of £120 spent in the before-mentioned experiments. The pavement in Fulham Road cost 10*s.* 3*d.* per square yard, the difference being partially attributable to the fact that a portion of the old broken granite was used in the concrete foundation in lieu of ballast.

The details of the cost per square yard, are as follows, viz.:—

Item.	31,333 yards in Sloane Street and King's Road in 1879.	10,573 yards in Fulham Road in 1881.
	d.	*d.*
Labour in breaking up macadam surface and excavating	11·00	11·00
Cartage of old materials, including shoot for rubbish .	9·04	9·80
Portland cement for concrete and grout	20·02	17·17
Thames ballast and sand for concrete, grout, and top dressing	8·56	5·80
Blocks	58·66	60·82
Studs	1·58	1·48
Labour in bottoming up and levelling, preparing and laying concrete, fixing studs in, wheeling, and laying blocks, grouting, top dressing, watching and sundries	13·45	14·12
Labour and materials in permanently filling in margins	0·86	0·90
Sundries—plant, tools, superintendence, testing cement, oil, repairs, &c.	2·92	1·85
Total	126·09	122·94

NOTE.—No allowance is made for the value of the paving stones and broken granite taken up and re-used in other parts of the district, the minimum value of which amounted to £2,050, or about 1*s.* per square yard.

[1] Minutes of Proceedings Inst. C.E., vol. lviii., p. 75.]

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A reference to the Appendix, Table IV., will show that the variation in the prices paid for wood pavement in various parts of the Metropolis has been somewhat remarkable, the maximum cost per square yard for laying a pavement and concrete foundation with entirely new materials, having amounted to 18*s.* 6*d.*, and the minimum to 10*s.* 6*d.* Owing presumably to competition and to the experience which has been gained, together with increased facilities, the cost has gradually been reduced to reasonable limits, as compared with the charges made eight or nine years since.

Management.—However excellently a street carriageway pavement may have been constructed, its condition will soon become unsatisfactory unless its maintenance receives proper supervision. Good management implies not only that repairs shall be promptly and efficiently executed, but that the services of cleansing, watering, and sanding must be properly carried out; in short, the essentials of proper management are to be found in the judicious application of the scraper and broom, of water, and of grit, and in the immediate removal of defective blocks. The reinstatement of gas, water, and drainage-trenches must be classed under the first heading; and, although an apparently small matter, yet from the frequency of such openings, so serious an interference with the street surface is created, that in the course of a few years surface uniformity cannot be maintained unless this work is very carefully executed, and ample time allowed to elapse before the traffic is allowed to pass over the work. After a pavement has been laid for three years the existence of defective blocks becomes apparent, as by this time, the first effect of compression having ceased, the fibres of such blocks begin to yield under traffic pressure, with the result that slight surface depressions are formed. When this happens a bumping motion is created, and as the wheels then strike upon the edges of the adjoining blocks it is obvious that the surface must become irregular; and depressions or hollows a foot square or more are soon formed, which, unless promptly remedied, materially spoil the surface.

To avoid slipperiness and to ensure many of the advantages claimed for wood pavement, it is essential that a thorough and systematic service of cleansing must be carried out, especially where macadam pavements are contiguous to wood, as in damp weather a considerable amount of mud is imported from them. In connection with the wood pavement in Chelsea there is a regular street orderly service, by which horse-droppings are removed

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and deposited in bins. In addition thereto the wood pavements are washed once or twice a week, and are cleansed daily either by horse-sweeping machines or by hand-labour. In the absence of heavy rains mere sweeping fails to keep wood pavement clean, and washing then becomes essential. To effect this water vans are sent out before midnight, and the surface is so thoroughly soaked that, by the time the sweeping machines commence to work at 3 A.M., the dirt is easily removed, the entire operation being concluded in the forenoon. The ascertained cost of this service, including labour and horse hire in washing and sweeping, street orderly work, and collection and removal of the sweepings, amounts to 4½*d.* per square yard per annum, as against 11*d.* per square yard for macadam previous to the substitution of wood. It has been asserted upon good authority that the cost of cleansing wood pavement is very trivial; this is slightly misleading, the proportions being approximately—

Macadam	1·00
Wood	0·41

Theoretically the amount of mud created upon the surface of wood, as also in the case of asphalt, should be almost nil; but practically the Author finds that some 2,700 cartloads are annually removed from a length of about 3 miles in Chelsea. Therefore after making every allowance for the conversion into mud of 350 loads of sand placed on the wood when slippery, it is obvious that a great portion of the mud is imported from the adjacent macadam.

The plentiful application of water prior to the work of cleansing is most beneficial, both in preventing dust, and, from a sanitary point of view, in removing the cause of obnoxious smells; but as the Metropolitan water-supply is not yet in the hands of the ratepayers, its use for this purpose is materially restricted. The Author ventures to assert that the system of cleansing thus described is amply sufficient to obviate slippery surfaces caused by the accumulation of greasy mud, and that the summer watering may be so carried out that a minimum wetting will suffice to keep down the dust. Letters have recently appeared in the *Times* with reference to the watering and cleansing of wood pavements, in which it has been strongly urged that such pavements should not be watered at all. When it is considered in what an unskilful manner street-watering is sometimes done, and that, owing to the stupidity or carelessness of carmen, considerable danger to loco-

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motion is caused by overwatering a dirty pavement, there may be some justification for the contention. Doubtless horses travel better on dry wood pavement than on a watered surface, but in the absence of rain, watering is an absolute necessity for keeping down fine dust, more especially upon a hot windy day, when at least five or six wettings are required. Watering is also necessary for the preservation of the wood itself, as without water it would be materially injured by abrasion under such conditions. It is also questionable whether the very fine dust which must be given off under a non-watering system, would not become so serious as to be injurious to health and promote disease of the eye; but apart from this, the nuisance from the heat and dust combined would become intolerable.

In continuous damp and foggy weather and on frosty nights wood pavement is especially liable to become slippery; therefore, to ensure a safe foothold for horses, its surface should be covered with a thin layer of Thames sand or grit. In Chelsea it has been found that this operation can be more expeditiously and evenly carried out by horse-machines known as "sand-distributors" than by manual labour alone. Night gangs have been organized, and, according to the conditions of the weather, the machines are sent out either at night or early in the morning; in the latter case the whole of the wood is sanded and made fit for traffic by eight o'clock. The operation is beneficial to the wood itself, and might be advantageously carried out at other times, because the grit becomes so well worked into the ends or fibres of the blocks that it not only affords protection to them but ensures a better foothold for horses. The ascertained cost of the sanding does not exceed ½*d.* per square yard per annum.

Durability.—One of the most important factors in connection with durability is the amount of traffic to which the pavement is subjected. As the Author has been unable to obtain complete information thereon he has had to rest content with the available figures, and has reluctantly omitted results and comparison of other important streets. Table III. in the Appendix shows (1) the daily traffic weight per yard width; (2) the depth of annual wear of wood; and (3) the annual wear of wood as reduced to a standard of traffic equal to 750 tons per yard width daily, or 235,000 tons per annum, exclusive of Sundays. It is gratifying to remark that there is a growing tendency to make observations and keep records of traffic weight, wear, and cost, and it is only by these means that reliable data can be obtained. It is to be hoped,

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therefore, that both local authorities and wood-pavement companies will institute the desired inquiries, by which means much valuable experience and knowledge will be gained. The comparative annual wear reveals several inconsistencies, which are shown on the diagrams, Plate 10, illustrative of the merits of various pavements, and by Table V. in the Appendix. For instance, the wear of the asphaltic wood pavement in Fleet Street with the maximum traffic weight, or 24th on the list, is but 16th in point of wear, whereas the same system with 13th and 9th traffic-weight positions, takes the high places of 24th and 23rd in wear. Lloyd's pavement in Regent Street has an 8th traffic-weight position, but a 20th in wear. The wear of the Improved, of Henson's, and of the plain pitch-pine pavements compares favourably in all cases with the traffic weight. The lesson to be drawn from these figures would appear to be that the asphaltic and Lloyd's systems are not successful; and the Author cannot help regretting that Regent Street should have been paved upon these particular systems. The pavement in Parliament Street is stated to have worn ½ inch only in three and a quarter years, but it must not be forgotten that its real wear has scarcely begun, and that the traffic weight is high. Should its life be eight years (which is extremely doubtful), it would take a higher position, as the annual cost would probably be 1*s.* 8*d.* per square yard (Appendix, Table VI.).

It is interesting to notice that some pavements have exhibited a considerable degree of durability and have had a tolerably fair life (Appendix, Table VII.). In this Table the pavements and periods under the headings "actual" life relate to accomplished facts, while several under the heading "estimated" have already nearly realized the life allotted to them. In other cases the estimate is given after inspection and measurement or inquiry. The number of the pavements is necessarily restricted in consequence of the absence of traffic-weight records.

The Author inclines to the opinion that it is not desirable to lay blocks of a greater depth than will provide for a life of seven years, as very few pavements retain a good surface after about six years' wear. In the case of the pavements previously described which have attained a greater life than seven years, it is proper to explain that those periods were only ensured by the execution of frequent and somewhat costly repairs. For instance, a considerable number of new blocks, of depths varying from 3 inches to 5 inches, according to the extent of wear, had to be inserted in

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most cases, while in others the old blocks were taken up, reversed, and relaid. These operations, however, are very unsatisfactory both in appearance and ultimate result. Experience consequently suggests that if 5-inch blocks were adopted instead of 6-inch, it would be preferable; and the Author favours the opinion that the smaller depth would be found not only sufficient but more economical and suitable, and would obviate much patching. 5-inch blocks are cheaper by 10*s.* per thousand, and it is estimated that in the first cost and twice renewal of a pavement which has an annual traffic of 750 tons per yard width, there would be a reduction in cost of 1*s.* 6*d.* per square yard in fifteen years, or 1¼*d.* per square yard per annum. Even if the average annual wear of 6-inch blocks should prove to be very little, after seven years' wear, it will generally be found that the surface is irregular; but considerable hesitation is always shown before local authorities order the wood to be renewed, for fear that they may be accused of waste or extravagance in removing blocks which still retain a good depth, although they show a considerably worn and bumpy surface. In short, therefore, 5-inch blocks would give as good a surface and pavement as 6-inch blocks; there would be less waste of timber in renewal, and on the whole there is little doubt that pavements would be kept in a better condition. Blocks having a depth of 5 inches only have been laid in Oxford Street, Leadenhall Street, and Aldersgate Street, and in Kensington a large area has been laid on this system; and the result so far appears to be satisfactory.

The Author has obtained numerous specimens of blocks from various streets, and he submits nearly sixty, which have been taken from Regent Street, Pall Mall, Cannon Street, Oxford Street, Ludgate Hill, Brompton Road, Praed Street, Sloane Street, King's Road, and Fulham Road. It will be observed that the maximum depth of wood is from King's Road (pitch pine), which is 5⅝ inches after four and a half years' wear, and that the minimum is from Oxford Street (near Rathbone Place), which is 1⅝ inch after six years' wear.

Obviously there are local matters to be considered in connection with wood pavement, for instance, the effect of the traffic in a wood-paved street having a sharp gradient. This has not specially come under the Author's notice, except at Ludgate Hill, where the blocks laid in 1877 were removed in February 1884, having been, it is alleged, "kicked out" by horses' shoes, and not fairly worn out by vehicles. The inclination of the carriageway of

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Ludgate Hill is 1 in 25. Similar results are noticeable at the western approach to Hyde Park Corner, at which place the inclination is 1 in 37. The question of gradient in wood-paved streets is also an important factor in regard to the tractive action of horses and the limit of safety for foothold, and it is regrettable that so little experience thereon is extant. In the City the steepest gradient paved with wood is in Ludgate Hill, in some parts of Piccadilly the inclination is 1 in 25; it might therefore be assumed that so far as actual safety is concerned, a gradient of 1 in 20 would not be too steep. In Chelsea the main roads are tolerably level, but there is little doubt that the annual wear of the blocks in King's Road (0·144 inch) is greater in consequence of the increased amount of omnibus traffic which has recently taken place, as, owing to a keen competition, omnibuses have been very rapidly driven along the street at times. A considerable amount of light traffic has also seriously tried the wood. In Sloane Street the nature of the traffic calls for no particular observation, and the annual wear of the wood (0·065 inch), together with the traffic-standard wear, gives a result which compares favourably and satisfactorily with any other street in London.

To ensure durability, it may briefly be asserted, that next to sound construction it is highly important that the number of openings for gas- and water-services should be limited, and that undue wear and tear can be mitigated by efficient cleansing and sanding. Neglect of the latter not only creates slipperiness, but is followed by permanent injury to the pavement itself.

In support of the Author's views, he submits a number of blocks as taken up from various streets in the Metropolis. Some are remarkable as specimens of excellent durability, while others exhibit considerable wear, and the very thin ones have created great surprise that a pavement could be held together with blocks so much worn.

Cost of Maintenance.—The Author has frequently been asked whether the wood pavement laid in Chelsea has proved economical as compared with macadam, the answer to which may be found in the following statement, which is based upon the assumption that the average life of the wood-blocks will be seven years, and which shows that the first cost, repairs, renewals, and cleansing, if spread over a period of twenty years, amounts to 1*s.* 9*d.* per square yard, whereas the previous cost of repairing, renewing, and cleansing macadam, but exclusive of first cost, amounted to 2*s.* 10*d.* per yard.

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ESTIMATED COST of WOOD PAVEMENT per SQUARE YARD in CHELSEA, for a PERIOD of TWENTY YEARS.

	£.	s.	d.
First cost	0	10	6
Repairs	0	0	6
Renewal of blocks every seven years	0	12	8
Interest on loans (at 4 per cent.).	0	2	9
	20)1	6	5
Per annum	0	1	4
Add cleansing and sanding	0	0	5
Total	0	1	9

If the cost be spread over a period of fifteen years only, the figures will be increased to 1*s*. 8¾*d*. per yard per annum for the wood + 5*d*. for cleansing, or a total of 2*s*. 1¾*d*.

Under the above circumstances it may be fairly assumed that the annual cost of properly constructing, repairing, and renewing wood pavement, exclusive of cleansing, which is subjected to a traffic of 500 to 750 tons per yard width per day of sixteen hours, and leaving it in a thoroughly good condition at the expiration of fifteen years, does not exceed 1*s*. 9*d*. per square yard; whereas the average annual cost of repairing and renewing the macadamised carriageways in Sloane Street and King's Road formerly amounted to 1*s*. 11*d*. per square yard, and in Westminster similar repairs cost—

	s.	d.
In Parliament Street	2	10
„ Whitehall	2	10½
„ Victoria Street	2	0
„ Great George Street	1	8

No doubt many similar instances might be adduced, in support of the assertion that, as a paving material, wood possesses the advantage of economy, independently of the saving in cleansing.

The annual cost per square yard for laying and maintaining wood pavements in various localities, including interest on loans, is given in Table VI. in the Appendix. In most instances the actual cost has been supplied, and in the remainder it has been carefully estimated, after making due allowance for efficient and creditable maintenance.

The Author regrets that he has been unsuccessful in obtaining fuller information as to the cost per square yard relatively to

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traffic weight per yard width, but such information as he has obtained he has classified in the following Table, and from which certain deductions are drawn. Until local authorities, or those persons directly interested in the question, adopt measures for ascertaining the latter, a considerable amount of theory must necessarily be exercised in deciding the question of cost according to the weight of traffic.

System.	Daily Traffic Weight per yard Width of Pavement.				
	400 tons.	500 tons.	750 tons.	1,000 tons.	1,250 tons.
	s. d.	*s. d.*	*s. d.*	*s. d.*	*s. d.*
Plain yellow deal . .	1 4	..	1 9	..	1 10½
Plain pitch pine . . .	..	1 6	..	..	..
Creosoted yellow deal .	1 6½	1 10¾	..	..	..
Henson's	..	..	1 9½	1 9½	2 0
Improved	..	..	..	1 11	2 1½
Asphaltic	..	..	2 0	..	2 0½
Lloyd's	..	..	2 2	..	..

The figures undoubtedly give the plain system of pavement the highest position in an economical point of view, and show the comparative cost of other systems in a manner not hitherto attainable.

It is apparent that as the minimum net cost of a soundly constructed and properly maintained wood pavement amounts to 1*s.* 9*d.* per square yard for a traffic of 500, and not exceeding 750, tons per yard width, the absurdity of some of the maintenance contracts which have been entered into is remarkable. On the other hand, a good bargain was made by the Improved Wood Pavement Co. in 1876, when they undertook to lay and maintain a large area in Piccadilly, also upwards of 2,000 square yards in King's Road, upon the "deferred payment" system, the rate for Piccadilly being 3*s.* per square yard per annum for a period of fifteen years. The result will consequently be that no less than 45*s.* per square yard will eventually be paid for an expenditure which in all probability will not greatly exceed 30*s.* In justice to the authorities, who entered into so costly a contract, it should be stated that in the year 1876 the modern system of wood pavement was in its infancy, and that public bodies were somewhat timid in

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incurring large outlays thereon; and as the contract stipulated that payment would cease immediately the contractors failed to efficiently maintain the pavement, it was considered that the risk would be small, as a proportionate amount only would have been paid.

Much trouble has been caused by public boards accepting low tenders for first cost, and ridiculously low terms for continuous maintenance, and it has been truly stated on a former occasion by Mr. Burt,[1] that some persons "were running a race to see which could get ruined the fastest." This prophecy has been literally fulfilled, but unfortunately, as in the case of asphalt and other systems of pavement when improperly undertaken, the consequences had seriously damaged the reputation of wood pavement. Considering that persons enter into contracts to efficiently maintain large areas of pavements with a daily traffic of 600 or 700 tons per yard width, for a period of fifteen years, for the sum of 9*s.* per yard, whereas the net cost in all probability will amount to 13*s.*, it is obvious that either the pavements will be insufficiently repaired or renewed, and the reputation of wood injured, or that "a day of reckoning" must come. With the experience already gained, it cannot be too strongly urged that public authorities should look ahead, and not accept a tender merely because it happens to be the lowest. Another matter ought perhaps to be mentioned, although, perhaps, a somewhat invidious one, namely, that ample and competent supervision should be provided, so that every detail in the execution of the works, especially the rejection of unsound blocks, may receive attention. The operation of inspecting every block is undoubtedly tedious; for example, in the Chelsea works, where the timber supplied was of fair quality, it was found necessary to separately sort out, reject, and mark about one block in twenty, the rejections being ninety-six thousand out of a total delivery of nearly two millions; and there is little doubt that, owing to the hurry of the work, many blocks were laid which escaped rejection, but assuredly these will be the first to fail. In works of considerable extent it would undoubtedly be a prudent expenditure to employ a competent inspector to look after the blocks alone.

To sum up, the Author ventures to assert that a properly constructed and kept wood pavement meets with favour. He has personally ascertained that shopkeepers and residents like it, in

[1] Minutes of Proceedings Inst. C.E., vol. lviii., p. 79.

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consequence of the absence of noise, and the absence of the inconvenience usually experienced by the frequent closing of the carriageway for repairs, as in the case of macadam; that cabmen give it their unqualified approval; and that the Managing Director of the London General Omnibus Co. prefers it, if properly kept, to either granite, asphalt, or macadam. Of course, exceptions have to be made in this as in all other cases, but the public generally appear to be satisfied with it. There are sections of the community, however, who do not view it with favour, especially carriage-builders, wheelwrights, saddlers, and granite merchants; but their disapproval will be readily understood. The improved condition of the carriageways of some of the best thoroughfares has also created a favourable impression upon strangers which has not been lost, inasmuch as deputations have inspected the various systems and made numerous inquiries into their respective merits, not only on the part of the municipalities of the principal towns in Great Britain, but from France, Germany, and other countries. At the present time a large amount of wood pavement is being laid in Paris and Berlin by the Improved Wood Pavement Co.

The Author has described somewhat fully the details of what may be considered to be mere ordinary matters, but as the success or failure of wood pavement mainly depends upon a careful consideration of apparent trifles, he trusts that he may be pardoned for having taken this course. He is of opinion that local authorities should invariably adopt measures for ascertaining the traffic-weight per yard width in a street before deciding to lay down wood pavement, as such information might prevent contractors from submitting a maintenance-tender regardless of the duty the pavement has to perform, and that complete records of annual cost and wear should be kept. He again ventures to remark that it cannot be too strongly urged that the greatest discretion should be exercised in the acceptance of tenders for construction and maintenance, and that no reasonable expense should be spared in providing ample and competent supervision. Under these circumstances he is of opinion that a close-jointed plain system of pavement, judiciously and faithfully carried out, and improved upon from time to time, will give good economic results, as well as ensure a sound and suitable carriageway pavement.

Lastly, the Author submits:

(1.) That where the ascertained annual cost of maintaining and cleansing a macadamized carriageway exceeds 2*s.* 2*d.* per square

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yard, or where the traffic is so considerable that a quieter and cleaner pavement is deemed essential, the substitution of wood is desirable.

(2.) That experience has proved wood pavement to be an economical and a convenient carriageway pavement for the streets of the Metropolis.

(3.) That, notwithstanding many former instances of failure, the modern system has achieved a fair amount of success, and there is no apparent reason why its use should not be extended.

The Paper is accompanied by several diagrams, from which Plates 9 and 10, and the woodcuts in the text, have been prepared.

[APPENDIX.

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APPENDIX.

I.—Mileage and Nature of Metropolitan Street carriage-way Pavements, March 1884.

District.	Total length.	Consisting of: Macadam.	Granite.	Wood.	Asphalt.	Flints or Gravel.	"Private" Streets.	Area of Wood.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Sq. yards.
1. Islington . .	160	30	12	..	..	78	40	..
2. Lambeth . .	134	21	2	3	..	105	3	16,000
3. Camberwell .	114	21	4	..	..	54	35	..
4. Hackney . .	99	42	4	..	..	46	7	1,000
5. St. Pancras .	85	20	20	1½	..	42½	1	33,593
6. Lewisham. .	80	20	..	..	..	40	20	..
7. Kensington .	78	20	..	9	..	44	5	167,798
8. Greenwich .	70	20	6	..	..	34	10	600
9. Fulham . .	65½	17	..	1¼	..	35¼	12	22,000
10. Marylebone .	65	25	15	3	..	22	..	80,000
11. Battersea . .	56½	10½	1	..	..	32½	12½	..
12. Streatham. .	56	6	..	..	..	20	30	..
13. Shoreditch .	51½	10	12	..	..	29	½	1,050
14. Poplar . . .	51½	16	5¾	¼	..	29½	..	2,400
15. Hampstead .	51	20	1	..	..	17	13	500
16. Bethnal Green	51	30	18	..	..	..	3	..
17. Paddington .	46½	14½	6¾	7½	..	16½	1	133,457
18. St. George's, Hanover Sq. .	41½	23½	..	8	..	10	..	109,486
19. Chelsea . .	38½	20¾	1¾	2¾	..	9¾	3½	49,500
20. Mile End . .	38	24	4	..	..	8½	1½	..
21. Newington .	37¾	8	4	½	¼	24¼	¾	6,600
22. City . . .	36	..	19½	6½	10	..	..	118,300
23. Plumstead .	36	14	..	..	..	16	6	..
24. Charlton, Lee, &c.	33	7	..	..	..	20	6	..
25. Wandsworth .	31	11	..	..	..	10	10	..
26. Bermondsey .	30½	18	12	..	..	..	½	410
27. Westminster .	26½	10	6	3	..	7	½	76,967
28. Putney. . .	26½	10	..	..	..	8½	8	..
29. Clapham . .	26½	7½	1¼	¼	⅛	13⅞	3½	4,000
30. Limehouse .	26¼	3	18	..	..	5	¼	1,000
31. Southwark .	23¼	13	3¾	¼	..	..	6¼	3,000
32. Woolwich . .	22	12	1½	..	..	6½	2	..
33. Clerkenwell .	20	7	13	..	..	..	..	..
34. Rotherhithe .	20	4	7	..	..	4	5	..
35. Whitechapel .	18	18	..	..	..	..	..	4,000
36. St. George's-in-the-East .	16	4	12	..	..	..	..	577
37. St. Luke's . .	15½	½	15	..	..	..	..	2,166
38. Holborn . .	15	¾	12¾	1¼	¼	..	..	16,644
39. St. Giles . .	14¾	2	10¾	¾	1¼	..	..	14,200
40. Eltham . .	14	3	..	..	..	10	1	..
41. St. James's, Westminster	13	5	5½	2	½	..	..	53,000
42. Strand . . .	10¼	..	9¼	½	½	..	..	8,000
43. St. Saviour's .	8½	2⅜	6	..	⅛	..	..	1,400
44. St. Martin-in-the-Fields .	6½	¾	3¼	2	½	..	..	50,000
45. St. Olave . .	6¼	..	6¼	..	..	..	..	2,000
46. Met. Board of Works . .	1¼	1¼	..	..	..	..	..	885
Totals . .	1,966½	573⅜	280	53¼	13½	798⅛	247¾	980,533

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II.—Particulars of tests of Cement from Wood-Pavement Works in King's Road

No. in Mr. Faija's testing-book Date received		114–1 April 10.		114–2 April 22.		114–3 June 6.		114–4 June 23.		114–5 Sept. 2.	
Fine- ness { residue on sieve 50×50 " " " 25×25		33 per cent. 3 "		31 per cent. 3½ "		25 per cent. 2½ "		29 per cent. 6 "		16 per cent. 2 "	
Weight per bushel . . . Specific gravity. . . .		113½ lbs. 2·95		114 lbs. ..		114 lbs. 3·02		114 lbs. 2·97		116 lbs. 3·09	
——	No.	Inch. 1¼×1¼	Av. per sq. in.	Inch. 1¼×1¼	Av. per sq. in.	Inch. 1¼×1¼	Av. per sq. in.	Inch. 1¼×1¼	Av. per sq. in.	Inch. 1¼×1¼	Av. per sq. in.
Tensile strength when 7 days old . . .	1	1,010		950		935		1,150		1,040	
	2	980		580		1,120		1,185		1,025	
	3	1,050	473	1,080	437	1,100	468	1,110		1,105	
	4	1,060		1,130		1,070		1,130		900	
	5	1,230		1,180		1,040		1,190	539	1,020	481
	6	..	..	..	..	..	..	1,300		1×1 460	
	7	..	..	..	..	..	..	1,260		540	
	8	..	..	..	..	..	..	1,375		540	
	9	..	..	..	..	..	..	1,290		545	
	10	..	..	..	..	..	..	..	..	460	
Tensile strength when 28 days old . . .	1	1,160		890		1,250		1×1 750		1×1 645	
	2	1,270		1,100		1,350		685		640	
	3	1,280	578	1,130	482	1,400	592	685	705	650	650
	4	1,330		1,050		1,250		720		670	
	5	1,470		1,260		1,410		685		645	
	6	..	..	..	..	..	..	..	..	..	..
	7	..	..	..	..	..	..	..	..	..	..
	8	..	..	..	..	..	..	..	..	..	..
	9	..	..	..	..	..	..	..	..	..	..
	10	..	..	..	..	..	..	..	..	..	..
Tensile strength when 3 months old . .	1	..	..	..	..	..	..	..	..	..	..
	2	..	..	..	..	..	..	..	..	..	..
	3	..	..	..	..	..	..	..	..	..	..
	4	..	..	..	..	..	..	..	..	..	..
	5	..	..	..	..	..	..	..	..	..	..
Tensile strength when 6 months old . .	1	..	..	..	..	..	..	..	..	940	
	2	..	..	..	..	..	..	..	..	860	
	3	..	..	..	..	..	..	..	..	910	886
	4	..	..	..	..	..	..	..	..	830	
	5	..	..	..	..	..	..	..	..	890	
Tensile strength when 9 months old . .	1	..	..	..	..	..	..	..	..	750	
	2	..	..	..	..	..	..	..	..	770	
	3	..	..	..	..	..	..	..	..	880	810
	4	..	..	..	..	..	..	..	..	840	
	5	..	..	..	..	..	..	..	..	..	
Tensile strength when 12 months old . .	1	..	..	..	..	..	..	..	..	825	
	2	..	..	..	..	..	..	..	..	860	
	3	..	..	..	..	..	..	..	..	835	867
	4	..	..	..	..	..	..	..	..	955	
	5	..	..	..	..	..	..	..	..	860	
Remarks from Mr. Faija's reports.		A good colour; very quick setting; should be warehoused before being used; very coarse.		Ditto.		Good colour; rather quick setting.		Ditto; very coarse.		Good colour; rather quick setting; better ground than the others.	

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and Sloane Street, made in 1879 by Mr. H. Faija, M. Inst. C.E.

114–6 Sept. 2.		114–7 Sept. 12.		114–8 Sept. 22.		114–9 Oct. 1.		114–10 Oct. 10.		114–11 Oct. 20.	
33 per cent. 8 ,,		28 per cent. 4 ,,		26 per cent. 4 ,,		30 per cent. 7 ,,		26 per cent. 4 ,,		19 per cent. 2 ,,	
118½ lbs. 2·9		118 lbs. 2·99		116 lbs. 2·96		111 lbs. 2·9		115 lbs. 3·05		120 lbs. 3·04	
Inch 1×1	Av. per sq. in.	Inch. 1×1	Av. per sq. in.	Inch. 1×1	Av. per sq. in.	Inch. 1×1	Av. per sq. in.	Inch. 1×1	Av. per sq. in.	Inch. 1×1	Av. per sq. in.
725	693	560	605	600	586	740	701	610	589	850	706
720		610		590		620		535		650	
640		625		580		710		530		760	
725		620		580		700		630		730	
625		640		590		720		620		650	
										1¼×1¼	
665		615		620		690		630		1,400	
660		550		550		755		600		1,450	
705		585		580		630		575		1,750	
715		645		..		690		600		1,750	
755		605		..		755		565		1,360	
710	728	810	772	800	767	710	718	590	764	750	690
740		750		870		730		810		680	
850		870		735		670		860		700	
720		820		775		660		800		590	
740		860		740		750		760		730	
640		750		665		740					
720		670		700		760					
680		650		870		710					
700				750		720					
780						730					
..	..	810	826	..	..	860	728	870	901		
..	..	770		..	..	690		925			
..	..	840		..	..	710		950			
..	..	900		..	..	720		860			
..	..	810		..	..	660					
..	..	..	..	*Note.* — When these briquettes were destroyed in Jan. 1883, some of them showed slight signs of having blown.		760	700				
..	..	..	..			780					
..	..	..	..			700					
..	..	..	..			650					
..	..	..	..			660					
Light colour: very quick setting; coarse.		Light colour; fairly quick setting; very coarse; sample slightly damaged in parts.		Light colour; fairly quick setting; very coarse; similar cement to last.		Light colour; very quick setting; badly ground; too fresh; must be warehoused.		Good colour; very slow setting; very coarse; different cement to any of the others.		Good colour; slow setting; better ground than most of the others; should be warehoused.	

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III.—Comparative Wear of Wood Pavements as reduced to a Traffic Standard.

Situation.	System.	Weight per yard Width per day of Sixteen Hours.	Depth of Annual Wear of Wood.	Comparative Annual Wear of Wood as reduced to a Traffic Standard of 750 tons per yard width per diem.
		Tons.	Inches.	Inches.
*Fleet Street . .	Asphaltic	1,360	0·456	0·251
Ludgate Hill . .	Improved	1,236	0·428	0·259
*Oxford Street .	Henson's (east section)	1,191	0·191	0·120
*Fleet Street . .	„	1,165	0·269	0·173
*Oxford Street. .	Plain	1,164	0·475	0·306
* „ „ .	Asphaltic	1,137	0·484	0·319
*Parliament Street	Improved	1,106	0·154	0·104
*Leadenhall Street	Henson's	1,000	0·264	0·198
*Oxford Street. .	„ (west section)	985	0·329	0·250
* „ „ . .	„ (central „)	948	0·323	0·255
*Leadenhall Street	Improved	808	0·200	0·186
Brompton Road .	Asphaltic	648	0·373	0·431
King's Road . .	Improved	603	0·157	0·195
Brompton Road .	Henson's	584	0·184	0·236
*Edgware Road .	Plain	584	0·198	0·254
*Regent Street .	Asphaltic	558	0·286	0·384
* „ „ .	Lloyd's.	558	0·214	0·288
King's Road . .	Improved (pitch pine)	558	0·089	0·119
„ „ . .	Plain	551	0·144	0·196
„ „ . .	Plain (asphalt bed) .	498	0·139	0·209
„ „ . .	Plain (pitch pine) .	468	0·055	0·088
„ „ . .	Creosoted blocks (mastic joint) . . .	434	0·139	0·240
„ „ . .	„ „ (lime joint)	407	0·111	0·204
Sloane Street .	Plain	279	0·065	0·175

* Weight of traffic taken from Mr. Howarth's Paper in these instances.

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IV.—First Cost of various Wood Pavements in the Metropolis.

Situation.	Area in Square Yards.	When Laid.	System.	Cost per Square Yard. s. d.	Remarks.
Ludgate Hill	2,824	1873	Improved	18 0	
Aldersgate Street	6,884	1874	"	15 0	
Northumberland Avenue	6,100	1876	"	15 0	Exclusive of concrete foundation.
Leadenhall Street	2,177	1876	"	12 3	
Parliament Street	1,672	1880	"	18 8	
Oxford Street	3,838	1876	Asphaltic	15 6	
Strand	9,242	1877	"	13 6	
Fleet Street	2,614	1877	"	15 0	
Brompton Road	5,960	1878	"	13 9	
High Holborn	5,742	1879	"	15 4	
Regent Street	5,578	1880	"	12 6	
Oxford Street	6,980	1875	Henson's	16 6	
" "	4,114	1875	"	16 6	On 2 inches extra concrete.
Leadenhall Street	1,788	1876	"	18 6	
Oxford Street	6,301	1876	"	14 0	"
Fleet Street	3,541	1877	"	16 0	
Brompton Road	7,148	1878	"	12 9	
Euston Road	6,000	1880	"	11 6	
Pall Mall	7,600	1879	Lloyd's "keyed"	8 5	On existing concrete.
Regent Street	11,053	1880	"	13 9	
Coleman Street	2,291	1875	Ligno-mineral	13 6	
Cannon Street	9,051	1874	Carey	13 6	
High Street, Kensington	1,714	1877	Plain	14 0	
Fulham Road	1,587	1878	"	14 0	
High Street, Notting Hill	7,102	1878	"	12 6	
Oxford Street	12,861	1878	"	8 4½	"
Edgware Road	14,639	1880	"	8 4½	"
Sloane Street	13,624	1879	"	10 6	
King's Road	14,253	1879	"	10 6	
" "	756	1879	Pitch pine	11 8	
" "	194	1879	Creosoted blocks and mastic joint	14 2	
" "	300	1879	Do. and lime joint	11 10	
" "	131	1879	Asphalt bed	12 4	
Praed Street	7,239	1879	Plain	10 7	

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V.—COMPARATIVE MERITS of VARIOUS PAVEMENTS, where the TRAFFIC WEIGHT and WEAR of WOOD are KNOWN. SUMMARISED from TABLES III. and VI., and PLACED in their RELATIVE ORDER, COMMENCING with the GREATEST in EACH INSTANCE.

Description of Pavement according to Traffic Weight. (Table III.)	Annual Wear of Wood. (Table III.)	Annual Wear of Wood as reduced to a Traffic Standard of 750 tons (Table III.)	Annual Cost for Fifteen Years. (Table VI.)
1. Fleet Street (asphaltic)	Oxford Street (asphaltic)	Brompton Road (asphaltic)	King's Rd. (improved).
2. Ludgate Hill (improved)	,, ,, (plain)	Regent St. (asphaltic)	,, ,, (improved, pitch pine).
3. Oxford St. (E.) (Henson's).	Fleet St. (asphaltic).	Oxford St. (asphaltic)	Ludgate Hill (improved).
4. Fleet St. (Henson's)	Ludgate Hill (improved)	,, ,, (plain)	Leadenhall St. (Henson's).
5. Oxford St. (plain)	Brompton Rd. (asphaltic)	Regent St. (Lloyd's)	Oxford St. (asphaltic).
6. ,, ,, (asphaltic)	Oxford St. (W.) (Henson's)	Ludgate Hill (improved)	Regent St. (Lloyd's).
7. Parliament St. (improved)	,, ,, (C.) (Henson's)	Oxford St. (C.) (Henson's)	Parliament St. (improved).
8. Leadenhall St. (Henson's)	Regent St. (asphaltic)	Edgware Rd. (plain)	Brompton Rd. (Henson's).
9. Oxford St. (W.) (Henson's)	Fleet St. (Henson's).	Fleet St. (asphaltic)	,, ,, (asphaltic).
10. ,, ,, (C.) (Henson's).	Leadenhall St. (Henson's)	Oxford St. (W.) (Henson's)	Fleet St. (Henson's).
11. Leadenhall St. (improved).	Regent St. (Lloyd's)	King's Rd. (creosoted, mastic)	,, ,, (asphaltic).
12. Brompton Rd. (asphaltic)	Leadenhall St. (improved)	Brompton Rd. (Henson's)	Regent St. (asphaltic).
13. King's Rd. (improved)	Edgware Rd. (plain)	King's Rd. (plain, asphalt bed)	King's Rd. (creosoted, mastic).
14. Brompton Rd. (Henson's)	Oxford St. (E.) (Henson's)	,, ,, (creosoted, lime)	Oxford St. (W.) (Henson's).
15. Edgware Rd. (plain)	Brompton Rd. (Henson's)	Leadenhall St. (Henson's)	,, ,, (E.) (Henson's).
16. Regent St. (asphaltic)	King's Rd. (improved)	King's Rd. (plain)	King's Rd. (plain, asphalt bed).
17. ,, ,, (Lloyd's)	Parliament St. (improved)	,, ,, (improved)	Oxford St. (plain).
18. King's Rd. (improved, pitch pine).	King's Rd. (plain)	Leadenhall St. (improved)	Edgware Rd. (plain).
19. ,, ,, (plain)	,, ,, (plain, asphalt bed)	Sloane St. (plain)	Leadenhall St. (improved).
20. ,, ,, (plain on asphalt bed).	,, ,, (creosoted-mastic)	Fleet St. (Henson's)	Kind's Rd. (plain).
21. ,, ,, (plain, pitch pine)	,, ,, (creosoted-lime)	Oxford St. (E.) (Henson's)	Oxford St. (C.) (Henson's).
22. ,, ,, (creosoted, mastic)	,, ,, (improved pitch pine)	King's Rd. (improved, pitch pine).	King's Rd. (creosoted, lime).
23. ,, ,, (creosoted, lime)	Sloane St. (plain)	Parliament St. (improved)	,, ,, (plain, pitch pine).
24. Sloane St. (plain)	King's Rd. (plain, pitch pine)	King's Rd. (plain, pitch pine).	Sloane St. (plain).

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VI.—Annual Cost of various Wood Pavements.

System.	Situation.	Traffic weight per yard width per diem in Tons.	Annual Cost per square yard for First Cost, Renewals, Repairs, and Interest on Loans (exclusive of Cleansing) if spread over a period of fifteen years.	
			s.	d.
Plain	Sloane Street	279	1	3¾
Henson's	Euston Road	700	1	5¼
Plain (pitch pine) . .	King's Road	468	1	6
Creosoted blocks (lime joint)	" "	407	1	6½
Henson's	Oxford Street (C.) . .	948	1	8½
Plain	King's Road	551	1	8¾
Improved	Leadenhall Street . .	808	1	9¾
Asphaltic	Strand	1,100	1	10
Plain	Edgware Road . . .	584	1	10¼
"	Oxford Street . . .	1,164	1	10¼
" (asphaltic bed) .	King's Road	498	1	10½
Henson's	Oxford Street (E.) . .	1,191	1	10¾
"	Oxford Street (W.) . .	985	1	10¾
Creosoted blocks (mastic joint)	King's Road	434	1	10¾
Asphaltic	Regent Street . . .	558	2	0
Improved	Aldersgate Street . .	..	2	0
"	Northumberland Avenue	..	2	0
Asphaltic	Fleet Street	1,359	2	0¼
Henson's	" "	1,165	2	1
Improved	Oxford Street. . . .	985	2	1
Asphaltic	Brompton Road . . .	648	2	1
Henson's	" "	584	2	1½
Improved	Parliament Street . .	1,106	2	1½
Lloyd's	Regent Street . . .	558	2	2
Asphaltic	Oxford Street. . . .	1,137	2	2¼
Carey's	Cannon Street . . .	..	2	4
Henson's	Leadenhall Street . .	1,000	2	8½
Improved	Ludgate Hill . . .	1,236	2	9½
"	Piccadilly	800	3	0
"	Knightsbridge . . .	780	3	0
" (pitch pine) .	King's Road	558	3	2
"	" "	603	3	2

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VII.—Life of various Wood Pavements.

System.	Situation.	Traffic weight per yard width per diem in Tons.	Life of Wood in Years. Actual.	Life of Wood in Years. Estimated.
Improved	Aldersgate Street	..	9·50	..
"	Northumberland Avenue	..	..	9·0
Plain (pitch pine)	King's Road	468	..	9·0
Carey's	Cannon Street	..	8·00	..
Henson's	Oxford Street (C.)	948	..	8·0
Creosoted blocks (mastic joint)	King's Road	434	..	8·0
Creosoted blocks (lime joint)	" "	407	..	8·0
Plain	Sloane Street	279	..	8·0
Henson's	Oxford Street (E.)	1,191	7·84	..
"	Oxford Street (W.)	985	7·58	..
"	Leadenhall Street	1,000	7·50	..
Improved	Ludgate Hill	1,236	7·00	..
"	Oxford Street	985	7·00	..
" (pitch pine)	King's Road	558	7·00	..
Asphaltic	Fleet Street	1,360	..	7·0
Henson's	" "	1,165	..	7·0
Improved	Parliament Street	1,106	..	7·0
"	King's Road	603	..	7·0
Plain	Edgware Road	584	..	7·0
"	King's Road	551	..	7·0
" (asphalt bed)	" "	498	..	7·0
"	Oxford Street	1,164	..	6·5
Asphaltic	Brompton Road	648	..	6·5
Henson's	" "	584	..	6·5
Asphaltic	Oxford Street	1,137	6·20	..
Improved	Leadenhall Street	808	..	6·0
Asphaltic	Regent Street	558	..	6·0
Lloyd's	" "	558	..	6·0
Asphaltic	Strand	1,100	5·50	..
Improved	Knightsbridge	780	5·50	..
Lloyd's	Pall Mall	..	5·00	..

[Discussion.

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Discussion.

Mr. G. H. STAYTON said he had been told that his Paper did not deal with the obnoxious smells sometimes experienced in connection with wood pavement. He thought, however, that he had dealt with the subject fully under the head of management; he had certainly intended to do so by drawing attention to the absolute necessity for a plentiful supply of water for the purposes of cleansing. Of some samples of wood pavement which he exhibited, one block had been taken up from Oxford Street a month or six weeks ago, and it showed that wood pavement could be worn down to the thickness of a mere crust, and still retain a fair surface. It was originally about 6 inches in depth, and was laid in 1878. The wear was simply owing to the traffic upon it. Mr. Stayton.

Sir JOSEPH BAZALGETTE, C.B., President, asked if the Author could give any further opinion on the subject of traction and foothold with wood pavement as compared with other kinds of pavement. Sir Joseph Bazalgette.

Mr. STAYTON said he could give no further opinion on the subject. It had been exhaustively treated a few years ago by Mr. W. Haywood, the City engineer; he had not, therefore, thought it necessary to deal with it again. The average thickness of the pavement at present in Oxford Street was about 3·30 inches; but at certain parts it was not thicker than the block to which he had drawn attention ($1\frac{5}{8}$ inch), which was a fair specimen of the pavement at those parts where the traffic was concentrated. Mr. Stayton.

Mr. W. LAWFORD remembered when, in 1841, a part of Whitehall and a part of St. Giles were laid with Rankin's patent wood pavement. It was down only six or eight months when it failed, owing, as he believed, to insufficient drainage and a bad foundation; besides which the cost came to £2 10*s.* or £3 per square yard. The success of the present wood pavements was no doubt largely owing to the good foundations on which they were laid. He remembered seeing the pavement put down between the Chapel Royal, Whitehall, and the Horse Guards. There was no concrete, but only a wood framing as a sub-structure. A full description of it, with illustrations, would be found in 'The Civil Engineers and Architects Journal,' for September, 1841.[1] From Mr. Lawford.

[1] Vol. iv., p. 307.

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Mr. Lawford. the same publication he found that in 1838 many streets in Philadelphia were paved with wood, and he believed that the pavement remained to the present day, but he did not know the results.

Mr. Weaver. Mr. W. WEAVER considered that some apology was due from him as Surveyor of the parish of Kensington, where by far the largest area of wood pavement had been laid, for not having presented a Paper on the subject to the Institution. He agreed with the Author in the three propositions at the end of the Paper, especially the third, that notwithstanding many former instances of failure, the modern system had achieved a fair amount of success, and that there was no apparent reason why its use should not be extended. So far from this, he thought its use should be very much extended in consequence of an injunction that had lately been granted against his Board with reference to the use of steam-rollers. If that decision was not upset (the parish authorities were about to appeal against it) he did not think the public would like to revert to the state of things existing twenty years ago, when the traffic had to plough its way through the newly-laid macadam, and in such case wood pavement was likely to extend very much. There were some details on which he could not quite agree with the Author, one of which was the statement that wood pavement was laid down better and cheaper in Chelsea than in any other part of London. In Kensington seven different kinds of pavement had been tried—he believed every known kind except Carey's keyed-joint, and the result of his experience of those systems had led him to believe that the most economical wood pavement that could be laid was the plain deal, if it was to be laid under competitive tenders where the wood had to be inspected to see that it was of a proper description; but if the work was not tendered for, if a good price was given for a good article, and it was wished to have the work done expeditiously, he preferred the system of the Improved Wood Paving Co. with pickled blocks and asphalt joint. The work was got through much more rapidly in that way, and from the results in Kensington, he was sure that that system would last as long, if not longer, than the plain system; the cost, however, was about 1*s*. 6*d*. per square yard more. The assumed superior merits of the wood pavement in Chelsea appeared to be due, according to the Author, to the work having been executed by his own staff and the substitution of studs for asphalt or laths. But he could not see the advantage of the parish doing the work with their own staff. If they invited tenders for the supply of so many tons

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of Portland cement, so many cubic yards of Thames ballast, and for breaking up the surface, they had merely a series of competitive tenders for the work in detail, whereas in the other case they had one tender for the complete work; and he thought that the one profit in the latter case was less than the various profits in the other. He might mention a practical illustration which had come under his own notice in the Fulham Road. It was the last extensive piece of work that the Author had done, and at the same time Mr. Weaver was paving a portion of the same road under his charge extending from the Brompton Oratory to Thistle Grove. In his own case, the work was done by Messrs. Nowell and Robson under contract, at 9*s.* 5*d.* per yard, whereas in the Author's case it was 10*s.* 3*d.*, or 10*d.* a square yard more, and the time of execution was about 40 per cent. longer. It would be apparent to everyone practically acquainted with the subject that it was necessary to consider not only the question of cheapness in first cost, but the interests of those who were to find the money for the execution of the pavement, namely the ratepayers, some of whom were abutting frontagers; and it was a matter of considerable moment to a shopkeeper on a line of thoroughfare to have his receipts diminished £5 or £20 a week in consequence of the road being up. Time therefore was of great importance. Again there was a great disadvantage in having to pick up the labourers almost as they came; it might take several weeks to get them into working condition; but if the order were given to an established firm they could at once send a number of men of experience in their several departments, so that they would get half way through their work before the others had started. The question as to when it became economical to substitute wood paving for macadamized roads was an important point for a Board to consider when about to launch a large wood-paving loan. His figures were not quite the same as the Author's, but they came to very much the same in the result. He was not able to separate the scavenging from the maintenance; but he had always advised his Board that if a macadamized road cost 1*s.* 6*d.* per square yard per annum for maintenance, it was cheaper to put down a wood pavement, and that was a very similar conclusion to the one at which the Author had arrived. With regard to the question of studs, he had tried various kinds, single pointed and double pointed, but his experience was that they did not produce such regular jointing as asphalt or lath joints, the lath being left in. If the lath was withdrawn the brooms passing over the surface sweeping in the liquid grout disturbed the regularity of the surface. Studs Mr. Weaver.

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Mr. Weaver. were generally driven in by boys, who were not models of carefulness, hence some were driven in very hard (perhaps after the men had had their dinner) while in other cases, when the men were fired, a good deal of the stud projected. He would leave the practical point as to superiority to be decided by members who could examine and contrast the two pieces of pavement in the Fulham Road to which he had alluded, that east of Thistle Grove, executed by Kensington, and the other portion west, carried out by Chelsea.

Mr. Isaacs. Mr. L. H. Isaacs regretted that he could not agree with either of the three proposals which the Author had asked the Institution to endorse. The Paper appeared to be written with optimist views, the Author having charge of a suburban or semi-suburban district, and apparently not being aware of what actual London traffic was. The instances of wear and tear which he had cited were confined to King's Road and Sloane Street. Mr. Isaacs desired to set against them the experience he had obtained in a central portion of London over which London traffic in the strict sense of the term actually passed. The statement that wood pavement was calculated to last seven or eight years was, he thought, misleading. He was ready to endorse all that had been said as to the comfort and convenience of wood pavement, but the question of cost ought also to be considered. The Author's first proposition stated that where the ascertained annual cost of maintaining and cleansing a macadamized carriage-way exceeded 2*s.* 2*d.* per square yard per annum, or where the traffic was so considerable that a quieter and cleaner pavement was deemed essential, the substitution of wood was desirable. He entirely agreed with the second part of the proposition, but the first was wrong. The Author had admitted that the statistics of his own office showed that the cleansing amounted to 11*d.* per square yard per annum, leaving for maintenance 1*s.* 3*d.* per square yard per annum. If he had gone to London proper, he would have found that the cost of mere maintenance was from 6*d.* to 1*s.* In his own district the cost in some streets was 6*d.*, in others 9*d.*, and in the majority 1*s.* Mr. Weaver had stated that about 1*s.* 6*d.* was the proper sum due to maintenance. Which was right? Or would engineers be justified in rejecting the advice of both, and taking instead the evidence of a man like Mr. Haywood, the City Engineer, who had charge of streets over which true London traffic passed? With regard to the economy of wood pavement, the Author had clearly failed to prove his proposition. It was certainly convenient, indeed luxurious, and where the ratepayers were willing

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to pay for the luxury, there was no reason why they should not have it. When a rich banker drew a cheque for the rates of his premises, rated perhaps at £10,000, it was of little consequence whether the amount of the cheque was £1,500 or £2,000. In like manner it was a matter of indifference to a wealthy inhabitant of Prince's Gate whether in drawing a cheque for the rates of his house the amount was £160 or £200. Such persons would rather draw for the larger amount and have the comfort of a noiseless pavement, than draw for the smaller amount and revert to the old state of things. The Author's third proposition "that notwithstanding many former instances of failure the modern system has achieved a fair amount of success, and that there is no apparent reason why its use should not be extended" had been drawn with great caution. There had been no doubt "a fair amount" of success, and enormous improvements had been made in the wooden pavements of the present day, as compared with those put down twenty-eight years ago; but, after all, the question was very largely one of cost. He would invite the members to consider Chancery Lane, Southampton Buildings, High Holborn, Lamb's Conduit Street, Hatton Garden, and Great Ormond Street, which it would be admitted were fair representatives of streets with ordinary London traffic. They were all under the jurisdiction of the Holborn District Board of Works. Chancery Lane was first laid with wood in the Michaelmas quarter of 1876 by the Improved Wood Pavement Co., which he thought was one of the best wood-paving companies in London. The area was 1,960 square yards, and the first cost was £1,557 10*s.*, or about 15*s.* per square yard. The complaints against it were numerous and grave. It was laid on the principle adopted by the Company of transverse boards, with concrete as a foundation. The noise of the traffic passing over the granite pavement which previously existed was so great that the dwellers in Stone Buildings and Chancery Lane petitioned the Board to lay down wood pavement, and even offered to contribute to the cost; but after it had been down a few years they complained of the shaking of the windows and the general unpleasantness, and asked that it might be taken up again. The Company, on being communicated with, stated that they had come to the conclusion that the system adopted was a mistake, and that they were prepared to alter it. To their credit it should be stated that they took up the whole of the pavement and relaid it at their own cost upon their modern improved system, with entirely new blocks and new

Mr. Isaacs.

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Mr. Isaacs. materials. That was in 1881, and no complaints as to rumbling and vibration had been made since that time. If the pavement lasted till 1886 he should think it would have done its duty, and he would have no cause of complaint. The wooden pavement of Southampton Buildings, where the traffic was much lighter than in Chancery Lane, was laid down in the Christmas quarter of 1876. It contained 1,063 yards superficial, and the cost was £824, or 15*s.* per square yard. It was largely relaid in the year 1882. The first pavement that he took in hand when he was appointed Surveyor of the Holborn District was the wood pavement in High Holborn, which he removed, and for which he substituted granite pavement in 1857. In the Christmas quarter of 1877 a wooden pavement was laid down in High Holborn. The portion in the Holborn District contained 3,842 yards superficial, and its cost was £3,030 1*s.*, which again was about 15*s.* per square yard. That pavement entirely failed to carry out the views, not only of himself and of the Board, but of the Company which supplied it, although they were paid the highest price for laying it down, and for subsequent maintenance. The pavement was continued through New Oxford Street, as far as Tottenham Court Road, and it was considered at the time as fine a sample of wood pavement as had been laid in London proper. In the early part of 1882, when the pavement had been down less than five years, it became evident that its life had gone, and that it would have to be taken up. It had been his duty to take up the portion in Holborn in sections, in the years 1882-3; and not one block laid in 1877 was now to be found there. He might also mention, lest it should be thought that the circumstance had arisen from some want of care on the part of the officials of the Holborn District, that the portion laid down in the St. Giles's district as far as Tottenham Court Road had also been removed and re-laid with Val de Travers asphalt. The wood pavement in Hatton Garden, which was considered a very suitable thoroughfare for the purpose, was laid in the Michaelmas quarter of 1878. It contained 4,679 yards superficial, and cost £3,743, or 15*s.* 6*d.* per square yard. It was laid in 1878, and yesterday, May 27th, 1884, the Val de Travers Asphalt Company proceeded to take it up, and they were now laying down asphalt in its stead. With those facts before them he asked the members of the Institution to pause before they too readily endorsed the propositions of the Author with reference to the economy of wood pavement.

Mr. Rich. Mr. W. E. Rich said, he thought the question asked by the President with reference to traction was most important. He

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believed that wood pavement was extremely favourable in regard to its low resistance to traction, and that was an important element which should encourage its extensive adoption. He hoped that some information would be forthcoming on the subject, obtained by means of the new dynamometer belonging to the Metropolitan Board of Works. He had himself had two hours' run with it a few months ago in some preliminary trials, and he had been surprised at the immense reduction in traction on going from a macadamized road to a wood pavement. He believed that the traction over a wood pavement did not exceed one half of that over a macadamized road, and it was much less than that over a stone pavement. Mr. Rich.

Mr. E. MATHESON inquired why the Author had omitted all reference to asphalt. The Paper seemed to imply that wood was the only alternative to macadam. Mr. William Haywood had exhausted the subject a few years ago, but he thought that later experience might induce him slightly to modify his views. In many respects asphalt was better than wood. The question of cost was not the only one to be considered. In regard to traction he had no doubt that asphalt was much superior to wood; but its alleged slipperiness had at first condemned it, and hindered its adoption. He believed it had been found that the difficulties connected with slipperiness had arisen from the inexperience of the drivers, and the strangeness of the new pavement to the horses. In Holborn, in the St. Giles's District, the wood pavement was about to be replaced with asphalt; and Cheapside also had an asphalt pavement. The low cost of cleaning, and the little delay in laying (an asphalt road being ready for use in twelve hours, while the Author of the Paper stated that wood pavement required a week), were important points in favour of asphalt over wood. Mr. Matheson.

Mr. HUGH MCINTOSH said that he had not had sufficient experience to give a decided opinion upon the question in dispute. In his district the authorities were only just beginning the use of wood. There were certainly some disadvantages connected with asphalt, with which he had made himself acquainted by observation and inquiry, and from which wood pavement was entirely free. The little experience he had had inclined him to favour wood in preference to asphalt. Mr. McIntosh.

Mr. J. LOVEGROVE remarked that only a very small area of wood pavement had been laid in his district. It was put down two years ago by the Improved Wood Pavement Co., and it had proved a successful piece of work. There were two rails passing through the centre of its width, and blocks of Guernsey granite, Mr. Lovegrove.

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Mr. Lovegrove. well dressed, were placed on each side of the rails. That was a very successful way of dealing with the difficulty of obtaining a comparatively noiseless pavement opposite a public building. They had had Val de Travers Asphalt at first, but the rails and the asphalt did not wear well together. Some years ago he had made some experiments with a view of testing the cost of the maintenance of macadamized roads, and the result was that he advised his Board that when the cost was found to reach 2*s*. per square yard, it was time to get rid of macadam and lay down wood or stone paving. There was a good deal of saving with wood and stone pavement in the matter of cartage, by far less mud being made than on macadamized roads. It was very important that all the information obtainable with reference to asphalt paving, pitching, and wood, should be laid before the members, and their thanks were therefore due to the Author for his efforts in that direction.[1]

Mr. Giles. Mr. A. Giles, M.P., considered that the Author had not done justice to the subject of creosote in his statement when he said that creosote to a certain extent closed the fibres of the wood, and tended to produce premature internal decay. Mr. Giles had had great experience in creosoting, and this was the first time that he had ever heard of creosote tending to promote premature decay. It was quite true that the pickling process was worse than useless, but if the blocks, before being laid, were properly creosoted they would last much longer than they did at present. It appeared from the statistics in the Paper that the actual wear was only 0·144, or $\frac{1}{7}$ inch per annum. The average duration of wood pavement was six or seven years, and as the blocks were 6 inches deep, they only lost about one-sixth of their depth in the whole period of their life. The destruction of wood pavement was caused, not so much by wear as by decay, for every one must have noticed that when wood pavement was being taken up, a great deal of it was as rotten as touchwood. That would not occur if the wood were properly creosoted before being laid. He was sorry the Author had not gone back to the early days of wood pavement in 1842, of which Mr. Giles had a lively recollection. It was nonsense to say that the slipperiness of wood pavement was only felt by inexperienced drivers, for there were certain states of the atmosphere when the pavement became so moist and greasy as to render it absolutely unsafe for horses. If something could be devised to prevent that

[1] Minutes of Proceedings Inst. C.E., vol. lviii., p. 61.

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slipperiness, a great benefit would be conferred upon the travelling public. Mr. Giles.

Mr. S. B. Boulton said that he had had considerable experience in creosoting, but not much in the application of that process to wood pavement. It would appear that usually the paving blocks were merely dipped in creosote, and perhaps sometimes in a mixture of that and other more doubtful substances. Was this a wise course to pursue? It was well known how much the creosoting process had been improved by the abandonment, for ordinary engineering purposes, many years ago, of the mere steeping tank, in favour of the cylinder process by vacuum and pressure. In one instance referred to by the Author, that of the King's Road, the blocks appeared to have been prepared by the latter process. In this case only 7 lbs. of creosote per cubic foot had been injected. The "resources of civilization were not exhausted" however by the injection of so small a quantity. The Author had said that these blocks were, when taken up, moist internally, although it did not appear that they were unsound. The internal moisture could only have resulted from one of two causes, either that the wood was not dry enough at the time of creosoting, or that the quantity of creosote employed was insufficient to prevent the subsequent infiltration of water. Many engineers caused to be injected for railway sleepers and other timber, 10 lbs. and 12 lbs. of creosote per cubic foot. Even with these quantities the injection was partially superficial, but the creosote completely saturated the sap wood and softer parts of the timber, filling up all cracks and fissures, whilst the ends of the logs, for some inches up, were usually gorged with the creosote. Small pieces of timber like paving blocks should if prepared be saturated with creosote like the extremities of a sleeper. When timber was unprepared the ends of a log absorbed moisture freely; and this must be the case more especially with paving blocks. Moreover, it was not pure water to which the paving block was exposed. Ammoniacal products, the very class of substances which were used in experimental putrifying pits for hastening the decay of timber, were largely present in the moisture of the London streets. It spoke well for the paving blocks, and for the selection of the wood of which they had been made, that, unprepared or slightly prepared as they were, they had lasted as well as they had done. He was surprised to hear the Author of the Paper express the opinion that creosoting, by closing the fibres of the wood, tended to produce premature internal decay. General experience in this and other countries during the last forty-five Mr. Boulton.

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Mr. Boulton. years was entirely to the contrary. There had recently been exhibited at the Institution a large collection of specimens of creosoted wood, sent by various railway administrations and from other sources, and which had been placed in many different kinds of soils. These specimens of ordinary creosoted fir timber had remained sound for periods varying from ten to thirty-two years, and showed conclusively that the creosote, which had filled up the outer portion of the fibres, had completely protected the inner portion of the wood from decay. To produce such results it was of course necessary that the wood should be deprived of moisture, and that the creosote should be of a suitable kind. The wearing away of the top surface of the blocks appeared to be rapid; any decay of the woody fibre would doubtless accelerate this abrasion. Creosote had not only a preservative, but also a hardening effect upon timber, and if thoroughly injected could scarcely fail to prolong the duration of paving blocks. As regarded the kind of timber to be used, he thought that a greater variety might be tried. Gothenburg had been spoken of, and excellent timber could be procured from that port, but no better than from various other Swedish ports, or from Memel, Danzic, or Riga. Beech he thought would do good service; it absorbed creosote remarkably well, and evidence had recently been brought forward of the very long duration of creosoted beech sleepers on the Western Railway of France. English elm also absorbed creosote readily, which was not the case with the American rock elm. He had recently taken three pieces of ordinary fir sleeper wood, three of English elm, and three of American elm, and had subjected them to the creosoting process under nine hours' pressure. The pieces of timber were all cut to the size of ordinary paving blocks, 6 inches by 6 inches by 3 inches. The results were:—

AVERAGE QUANTITY OF CREOSOTE ABSORBED PER CUBIC FOOT.

	Lbs.	oz.
Three pieces of fir	22	1
" " English elm	27	13
" " American elm	4	10

In forests through which he had travelled in Canada, the United States, Russia, and elsewhere, he had noticed a great waste of timber in cutting the lengths for the ordinary purposes of the market. If some uniform standard of size for paving-blocks were adopted in this country, and if it became known that there was a constant demand, much of this waste timber might be utilized by

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being cut into blocks, either in the forest or at the shipping port, whilst they could be brought here as convenient stowage for vessels at a very low rate of freight. He could remember some years ago when his offices were in King William Street, near London Bridge, the effect produced by taking up the granite pavement and substituting wood. No words can describe the sense of relief in the mitigation of the roar of a mighty traffic, which was at once experienced by all the busy toilers whose work had to be carried on amidst such surroundings. Mr. Boulton.

Mr. E. A. COWPER agreed that if blocks were creosoted at all they should be thoroughly saturated with creosote. It had been stated that the Author had not dealt with London streets where there was a very heavy traffic, but he had actually given the first cost and maintenance of the pavement in Ludgate Hill, Aldersgate Street, Leadenhall Street, Fleet Street, and Oxford Street. Mr. Cowper.

Mr. G. ALLAN did not think that wood pavement was a material to be recommended for further extension in the Metropolis. About fifteen years ago his attention was first directed to the question when the Val de Travers asphalt was brought before him. He first had it experimented upon in Bombay, where it was used to pave the footpaths of a number of leading thoroughfares, and it was in consequence of its success that he became the founder of the Val de Travers Co., and had the material introduced for the first time in London, their first contract being for Cheapside. When that contract was being carried out, Portland cement was used for the first time on an extensive scale. Lime was proposed, but upon his recommendation Portland cement was substituted in the contract, at an increased cost to the Company of £400. No doubt it was to the excellence of that concrete foundation that the success of the asphalt was due. Wood should be regarded as simply a temporary material for paving; so perishable an article should not be thought of for a moment for permanent use. As granite sets had given place to wood, so wood would have to give place to an impervious material, as asphalt, or some future improvement upon it. Both frost and sunshine had a very destructive action upon wood, or any material of an absorbent nature, but asphalt had no absorbent qualities, so that whatever wet might fall upon it it was rapidly dried up by the atmosphere. The reason why the use of asphalt had not rapidly extended was owing to the inefficient arrangements of the Metropolis. These had no doubt been improved of late years, but not sufficiently to justify vestries and other authorities in a further extension of asphalt. Asphalt pavement should be Mr. Allan.

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Mr. Allan. washed every morning as regularly as a stable or kitchen floor, and sanded if necessary, according to the state of the weather. If that were done, he believed asphalt would be everywhere demanded. In the case of wood sets there was nearly double the joint area of granite sets, and the joints were simply receptacles for dirt, mud, and horse droppings, which in dry weather were discharged in the form of dust. In asphalt there were no joints, and nothing to receive the droppings. All the dirt lay upon the surface, ready to be washed or swept away.

Mr. Stayton. Mr. G. H. STAYTON, in reply, said he had been glad to hear the various points discussed, particularly the criticisms of Mr. Isaacs; but he regretted the course he had taken, feeling convinced that his conclusions were wrong, especially as to cost, economy, and further extension. With regard to the question of absorption, he would only call attention to a block which had been four or five years in actual use in King's Road. It had been taken up from the centre of the road, and it showed clearly that the absorption had been practically nil. His experience had been that if the wood was sound there was no fear whatever of decay from absorption up to a certain point. He had no personal knowledge of the system of wood pavement referred to by Mr. Lawford as having been laid in 1841, neither had he ascertained the cause of its failure. The chief object of the Paper was to draw attention to the modern system, as from its unprecedented extension within the last few years more advantage might be gained by a consideration of its merits than by going back a period of forty-three years. The remarks of Mr. Weaver were valuable from his great practical experience in the question, and considerable weight might be attached to his opinions thereon. It was satisfactory to note that he concurred with the Author as to the advantages of the plain system, and the necessity for great care in the use of wood, but a few points demanded correction. In the first place it was to be regretted that Mr. Weaver should have fallen into the error of remarking that one of the Author's statements was "that wood pavement was laid down better and cheaper in Chelsea than in any other part of London." The statements advanced in the Paper did not in the least justify any such conclusion. He merely asserted that the Chelsea pavements comprised all the essentials of a sound and economical pavement, and that the result had been eminently satisfactory; but he readily admitted that the Improved Wood Pavement Company, Henson's Company, Messrs. Mowlem and Company, and Messrs. Nowell and Robson, had also carried out extremely good and

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creditable work. The nett cost of the Chelsea pavement in Fulham Road was rightly stated to have been 10*d.* per square yard more than the Kensington part, but Mr. Weaver was in error in asserting that the former took 40 per cent. longer time to execute. The Chelsea work had been commenced on the 5th of September, 1881, and was completed, and the road re-opened, on the 15th of November, thus giving 149 square yards per diem as the result, whilst the Kensington work was carried on in two sections between the 28th of August and the 21st of October, giving 143 square yards per diem for each section. The Kensington pavement had a large proportion of old macadam in the concrete, and the system of blocking which he considered objectionable (p. 264) had been adopted; and there was little question that the cost would eventually be as great as that of the Chelsea pavement. The wood-paving works, executed in Chelsea in 1879 by the Board's own staff, saved the ratepayers £3,160, which fact proved that the system might be attended with substantial advantages. Mr. Weaver's remark as to the difficulty of organizing an efficient staff was, in his experience, purely imaginary. The conclusion that when the cost of macadam exceeded 1*s.* 6*d.* per square yard per annum it was time to adopt wood, fully bore out the Author's view, inasmuch as the 2*s.* 2*d.* mentioned in the first proposition (p. 275) included 8*d.* for cleansing, thus leaving 1*s.* 6*d.* for repairs only. Notwithstanding what Mr. Weaver had urged against the use of studs, the Author's practical experience satisfied him that they were preferable to laths, as he had repeatedly seen considerable displacement of blocks, and irregular width of joints, where laths had been adopted. The statements of Mr. Isaacs were fallacious and misleading. He challenged the accuracy of the Author's conclusions, but failed to refute them by adducing a single reliable fact or figure as to annual cost of former or present maintenance, or records of traffic-weight, in justification of the position he had assumed. In a previous discussion in 1879, on street carriageway pavements, he also made certain statements at which Mr. Howarth expressed considerable surprise when correcting them.[1] Mr. Isaacs must either have paid no attention to the Paper and Tables attached thereto, or he must have neglected to formulate statistics as to weight of traffic and cost in his district, otherwise he could scarcely have made statements which had no practical value. Mr. Isaacs contended that London traffic, in the Mr. Stayton.

[1] Minutes of Proceedings Inst. C.E., vol. lviii., pp. 77, 88.

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Mr. Stayton. strict sense of the term, might be seen in the Holborn district, but not in the districts of Chelsea or Kensington. To a certain extent this was correct, but subject to qualification. In Holborn itself the daily maximum traffic-weight per yard width was approximately 1,100 tons, in Brompton Road it was 648 tons, and in King's Road 603 tons. The Author made due allowance for the variation in the traffic-weight in preparing the Table (p. 273), from which it might be assumed that the annual cost of the wood-paving in Holborn, if spread over a period of fifteen years, would be 2*s.* per yard, besides cleansing and sanding 5*d.*, or a total of 2*s.* 5*d.* Mr. Isaacs had made no attempt to supply figures upon this point, and without such information it could only be assumed that he had not given full attention to the subject. He had apparently intended to show that the experience of Mr. Weaver and the Author was such that their opinions upon wood pavements with "London traffic" ought not to be endorsed, but he failed to adduce any serviceable information in opposition to those opinions. It might, therefore, be assumed that he had taken no pains to make himself acquainted with the statistics relating to his experience, which would certainly have been an easy matter in so small a district as Holborn, which had but 15 miles of streets (of which ¾ mile only were macadamized, and 16,000 square yards were wood), whereas in Chelsea and Kensington combined there were 108 miles of streets, of which 41 miles were macadamized, and 217,000 square yards were wood. But apart from this, reference to Tables III. to VII. would show that the Paper dealt with pavements subjected to "London traffic" in its broadest sense. In Table VII. several instances were given in which the actual life of blocks had exceeded seven years, notwithstanding that the daily traffic-weight was upwards of 1,000 tons per yard width. Mr. Isaacs was evidently under a misapprehension as to the meaning of the item of 2*s.* 2*d.* per yard in the first proposition, as he deducted the 11*d.* for cleansing from 2*s.* 2*d.* instead of 2*s.* 10*d.*, as explained on pages 31 and 36, and in the foregoing reply to Mr. Weaver's remarks. The first proposition was, "That where the ascertained annual cost of maintaining and cleansing a macadamized carriage-way exceeds 2*s.* 2*d.* per square yard . . . . the substitution of wood is desirable." The figures (2*s.* 2*d.*) were arrived at by working out the cost of wood pavement, including first cost, interest on loans, repairs, renewals, and cleansing, for a period of fifteen years, in the following manner, viz.:—

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Mr. Stayton.

	s.	d.
First cost	10	6
Repairs	0	4
Renewals of blocks every seven years	12	8
Interest on loans	2	5
	25	11
Per annum	1	8¾
Add cleansing and sanding	0	5
Total	2	1¾

If, therefore, the Author's experience was of any practical value, he was satisfied that wood was undoubtedly a desirable and economical pavement as compared with macadam under the above-named circumstances. The observations of Mr. Rich respecting traction confirmed the statement in the Paper as to the low resistance of wood pavement to traction. The Author had not used the new dynamometer belonging to the Metropolitan Board of Works, but as regarded the average distance that a horse might be expected to travel without falling, Mr. W. Haywood, M. Inst. C.E., reported in 1874 that on granite it was 132 miles, on asphalt 191 miles, and on wood 446 miles, whilst the injuries to horses and obstructions to traffic were greatest on asphalt and least on wood. Mr. Matheson's remark that in many respects asphalt was better than wood coincided with the Author's views as expressed on p. 242, which also explained why the consideration of asphalt had been excluded from the Paper. Within the last month the entire carriageway of a street under the Author's charge had been paved by the French Asphalt Company, this system of pavement having been adopted principally on sanitary grounds. The Author did not agree with Mr. Allan that wood was likely to be superseded by asphalt, at any rate in the principal West End thoroughfares, unless the reputation of the former became damaged in consequence of their neglect, as described under the head of management. Obviously, both wood and asphalt needed constant attention in the matter of washing, cleansing, and sanding; but however suitable asphalt might be for footways, the Author could only repeat, that nothing but downright neglect in the management of wood was likely to lead to its extension, on account of slipperiness and the cruelty to horses which its adoption entailed. Mr. Giles and Mr. Boulton made some pertinent remarks as to creosoting. The Author in no way desired to do injustice to the system, his experience of creosoted piles having been favourable; but however desirable in theory it might be to creosote

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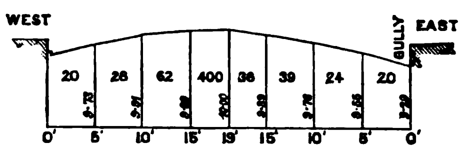
Mr. Stayton. wood-pavement blocks, his experience did not convince him that it was good in practice. Some few years since he had seen wood pavement taken up at Westminster, where creosoted blocks had been used. Many of the blocks were internally as rotten as touch-wood, and the sappy blocks had worn down greatly under the pressure of traffic. It was difficult to see that any advantage or economy could be gained by the adoption of creosote, and the Author was strongly of opinion that the surface of blocks gorged at the rate of 10 or 12 lbs. per cubic foot, would become so slippery, and the jointing so unsatisfactory, that the system would create dissatisfaction.

Correspondence.

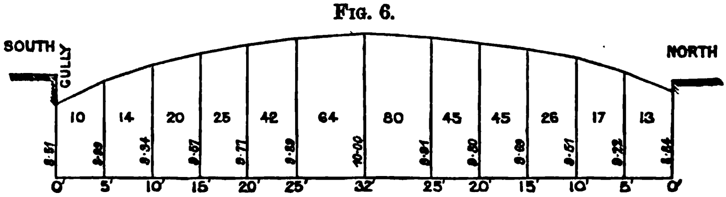
Mr. Culverwell. Mr. G. P. CULVERWELL approved of the contour of the carriage-way in Fig. 2, but thought that, if anything, the slopes might be reduced. It was ordinarily admitted that wood was a most slippery roadway, and thus every precaution should be taken. The sharp camber of the old macadam or stone pavement was too often followed, but it was unsuitable, and placed vehicles at a disadvantage, especially when starting from the kerb. The cross-section should be represented by two gradients, say of 1 in 40, from the channels to the crown, the latter being slightly eased off. In level roads the cross-section necessarily varied somewhat in order to drain to the gullies.

FIG. 5.



CROSS-SECTION, 49 SLOANE STREET.

FIG. 6.



CROSS-SECTION, 18 GREAT GEORGE STREET, WESTMINSTER.

Hor. Scale 1″ = 20′. Vert. Scale 1″ = 4′.

Figs. 5 and 6 were typical sections, and had been carefully taken recently. The east and south ends respectively were at

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gullies, whilst the west and north ends were midway between gullies, both streets being level. It was to be noted that steep gradients transversely were specially objectionable, as in this direction the blocks were made to abut close one to the other without any joint, and this gave little foothold. He did not comprehend the remarks as to pitch-pine producing a "jarring bumping motion." He had examined the portion of that pavement in King's Road, and travelled over it in various vehicles without noticing any increase of bumping motion, but there was somewhat greater resonance than where the wood was softer. He would expect to find the coefficient of elasticity of pitch-pine greater than of yellow wood. It was misleading to say that creosoting "tends to produce premature internal decay," although, indeed, perhaps the large amount of inferior work done in the market might form a sufficient excuse. Creosoting consisted in driving out the sap, and then substituting oil. If the first portion of the operation was not effected, the oil formed merely an external coating, preventing the sap from escaping, and "dry rot" set up. He, however, thought that creosoting was unnecessary, and even in some respects undesirable for wood paving. Creosote was chiefly of use in the case of porous woods exposed on all sides to the weather, in prolonging the ordinary life of the sapwood and wood next the sap. It did not render the sapwood harder, or better able to withstand abrasion under traffic; and it was almost useless to creosote the heart-wood of pitch-pine, the wood being already so full of resin that little oil was taken in. He had no hesitation in saying that the money expended in creosoting would be better laid out in the careful selection of heart-wood timber of uniform quality; and he thought there were data to show that the life of pitch-pine pavement might, without undue maintenance, easily reach ten to twelve years as a first-class roadway under the traffic standard of 750 tons per yard width per day. The depth of block should be regulated to some extent by the weight of traffic, the aim being that the block should be fairly worn out by abrasion just before decay from weather or other causes set in. With pitch-pine, even 5 inches appeared unnecessarily deep, considering that the maximum annual wear in King's Road was given as under 0·1 inch, and in Oxford Street blocks (presumably deal), worn as thin as $1\frac{5}{8}$ inch, had not failed under the traffic. Mr. Culverwell.

"Top-dressing" was important, but the material used was often unsuitable and too much was put on, with a result that, upon the first rain, the roadway was almost impassable for pedestrians, as

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Mr. Culverwell. in the case of the Strand at Charing Cross when last repaved. The material should be fine-screened sharp gravel, deposited in successive thin layers. Stones of the size of walnuts only rolled about, the wood not presenting a sufficiently hard anvil to crush them, and the material did not work its way into the wood so well when in a thick layer.

The opening up of streets for repairs to gas and water-mains, &c., was most objectionable, and peculiarly so in the case of wood pavement, owing to the time necessary for the proper restoration of the latter. It was to be regretted that a comprehensive scheme had not been carried out whereby to provide subway accommodation in the Metropolis for gas- and water-pipes, telegraph- and telephone-wires, &c. Many of the streets were much too narrow, whilst the evil daily increased, and thus every means should be taken to supplement their deficiencies.

More information was desirable so as to be able to determine the description of wood, size of block, and width of joint best adapted to varying conditions of traffic and gradient. He thought 1 in 20 too steep for any of the forms of wood-paving at present employed; and whenever the gradient exceeded 1 in 40, extra provision should be made for cleansing and sanding, especially in time of frost.

Sloane Street at present afforded a good opportunity for examination, as the paving and concrete foundation were being taken up throughout its whole length for a width of about 16 feet, in connection with new sewerage works. Such examination showed that the concrete foundation was clean and sound, and there was no appearance of moisture or objectionable matter having infiltrated. The blocks were not perceptibly rounded on top, and were in good condition, showing little soakage, and the cement grout bonded to them remarkably well. The cement joints were of uniform width, and were very little below the level of the blocks. The blocks were burred about $\frac{1}{8}$ inch upon the sides next the cement, and not at all at the ends where block bore against block. This pointed to the conclusion that blocks of uniform thickness, laid touching each other upon all four sides, and without any cement or other joint, would form a most durable pavement, whilst upon level roads it might give a sufficient foothold. The compression set up would effectually keep the blocks in place, and prevent infiltration of moisture. Expansion in the transverse direction of the street appeared to have been sufficiently allowed for, as the blocks bedded fairly upon the concrete, and no buckling away from it, or disturbance of the foot-pavements, had been noticed. That the compression

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in the longitudinal direction of street was great was evidenced by the line of blocks continually cambering towards the free end. This camber averaged about 1 inch in the excavation width of 16 feet. This showed the advisability of laying wood pavements in long even gradients: and where the vertical curves at the summit levels were sharp, expansion should be provided for, otherwise buckling, followed by disintegration, might take place. Compression was most desirable for wood, and directly added to the life of the blocks, whilst further preventing objectionable soakage. Hence it appeared why a rigid joint, such as cement, was preferable to a mastic one. In the latter case, in place of the wood being compressed, the substance of the joint itself was expelled, and part, no doubt (especially if the transverse expansion had not been allowed for) found its way underneath the blocks, and uneven bedding, followed by disintegration, resulted. In connection with this matter of compression appeared a direct objection to the use of creosoted blocks, as these did not expand, and compression was not set up, and also the cement grout did not bond to them as well as to plain ones. This explained the several instances noted by the Author of the ease with which creosoted blocks were taken up, and of the moisture having been found between them. Mr. Culverwell.

He was informed of one case—that of the long-girder bridge over the River Foyle, at Londonderry—in which the cement grout had never set. This the engineer in charge attributed, no doubt correctly, to the unremitting vibration night and day, as every care had been taken with the materials. Henson's patent felt bed and joint appeared peculiarly applicable to such cases.

In conclusion, he congratulated the Author upon having at an early stage adopted an excellent and economical system of pavement, singularly free from faults or objections, and one that bid fair, with minor modifications only, to be largely employed in the future.

Mr. W. H. DELANO regretted that the Author should have perpetuated confusion by using the words "asphalt," "asphaltic," when the substances he referred to were evidently gas-tar and gas-tar-mastic, namely, gas-tar mixed with chalk and gravel. Asphalt was a natural bituminous limestone; asphalt-mastic was the same, mixed with natural bitumen, and when mixed with grit was called gritted asphalt mastic.[1] He understood that pine sets cut from Swedish yellow deals 6 inches deep, 3 inches wide, and 8 to 11 inches long, laid on a Portland cement foundation 6 inches Mr. Delano.

[1] Minutes of Proceedings Inst. C.E., vol. lx., p. 249.

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Mr. Delano. thick, cost 10*s.* 6*d.* per square yard, exclusive of demolition of old roads, carting away old materials, and regulating the subsoil to proper contour. This price was low and probably misleading as a guide to contractors' prices for similar work, for it seemed to include no general expenses. A contractor paid rates and taxes, interest on money disbursed, cost of plant and tools, rent, employees, which made his general expenses from 15 to 20 per cent. Local boards, who were their own contractors, had none of these to count, but it was probable that their general expenses really exceeded those of a contractor, just as the management of railways by the State cost more than that of private companies. The standard traffic of 750 tons per yard width per diem seemed a misleading formula, for the wear and tear of a road did not depend so much upon the weight passing over it as upon the speed at which that weight travelled. There was also the important element of width of tire, the state of the atmosphere, the camber of the road, and the mode of traffic, cross, heavy, one side empty the other loaded, &c., &c. Take the new three-horse Paris omnibuses carrying, when full, forty-six people including driver and conductor, weighing when full 5½ tons, the width of the wheel tires being only 3½ inches, running at a speed of 7 to 9 miles an hour, and compare the same weight on a 4½-feet wide smooth cast-iron roller dragged at 1½ miles an hour. The latter improved a road, the former rapidly destroyed it.

The Author having alluded to the wood pavement laid down by the Improved Wood-Pavement Company in Paris, he would make some remarks on that interesting work, having watched it daily from its beginning. It had been carried out in September 1881 on a portion of the Boulevard Poissonnière, of the Rue Montmartre, and cross-road formed by the two. The gradient of the former was nearly 4 in 100. It had been laid by skilled English workmen, with the thicknesses of concrete and wood as above stated, and had resisted up to the present some of the heaviest traffic in the world. It was fair to state, however, that the winters of 1881–2–3 had been remarkably mild, and the summers of 1882-3 remarkably cool. In March 1884 the first repairs had been effected, and now (July 1884), although the road was in good order, some of the sets had become spongy, and those in the lines of traffic were rounded at the edges. On a wet day the wheels of the omnibuses, by expressing the surface-moisture, left seemingly white tracks behind them. Now, large surfaces of wood pavement were being laid all over Paris, chiefly in substitution of macadam, and four rival contractors were in the field. The price for all was as near alike as

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possible, say 23 francs the square metre, or 14*s.* 10*d.* the square yard; but it must be noted that the Paris octroi on cement was 12 francs the ton, and on wood 7 francs 50 cents the cubic metre, which increased the cost price by about 1 franc 50 cents the square metre, or say 1*s.* the square yard as compared with that of London. The system of deferred payments had been adopted all round; the prime cost of 23 francs was spread over a period of eighteen years, interest and compound interest being allowed on both sides at the rate of 7 per cent. per annum. This gave 2 francs 35 cents per annum for first cost, to which was added for maintenance 2 francs 50 cents per square metre per annum, equal to 4 francs 85 cents per square metre per annum for first cost and maintaining, for a period of eighteen years, or 3*s.* 1*d.* per square yard. This price had been subsequently increased so as to include demolition of old roads, but to a slight extent only. When Mr. Léon Say was Prefect of the Seine, in 1872, he repudiated the system of deferred payments, stating that it was a disguised loan, and that a municipality could always borrow money for work at a lower rate of interest than from a contractor. The above price was about what the Author considered a good contractor's bargain, as made by the Improved Wood-Pavement Company in 1876, for the maintenance of Piccadilly roadway for fifteen years. It had been often remarked that the materials for making roads were few, say stone sets or flags, wood, macadam, asphalt, the tesselated pavement laid in concrete by the Romans, and lava flags, as in Naples and Catania. Macadam was certainly condemned for heavy traffic in all large towns, as being too costly in maintenance and too disagreeable owing to its dust and mud, choking of drains, making mud-banks in rivers, &c., and the tendency of the day was to substitute for it a noiseless pavement. The macadamized road of the Champs Elysées, Paris, now nearly all replaced by wood, cost for maintenance 17 francs per square metre per annum, say 13*s.* 8*d.* per square yard; that of the Boulevards, 6*s.* 8*d.* per square yard. The proper way to lay wood was upon a smooth cement concrete. Concrete was being used in Paris now as a foundation for granite sets, as in Berlin and Vienna. Wood might answer for wide, well-ventilated thoroughfares, but to use it for narrow streets was anti-hygienic. Wood absorbed the urine of horses and the diluted filth of the street; horse-dung clung to it, and in dry weather it gave rise to horse-dung dust. Mr. Delano.

For traffic, wood was excellent for the first two or three years, but as soon as it became fibrous and worn, like an old tooth-brush, it would certainly produce poisonous emanations under a hot sun,

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Mr. Delano. and remain damp in winter. It lacked that first quality for a hygienic roadway, of impermeability; and was far less durable than asphalt; for Cheapside, laid in asphalt in 1870, had never been renewed, and its repairs had never stopped the traffic for one minute since it had been laid; whereas wood was entirely renewed in six to seven years. It might be safely predicted that a reaction would set in against wood within the next few years. The Paris engineers stated in Article 19 of their specification for wood pavements: "The administration reserves to itself the faculty of suppressing at any time any part whatever or even the whole of the roads paved with wood." He might add that the cost of the compressed-asphalt pavement now being laid round and inside the new Hotel des Postes, Paris (about 10,000 square metres), consisting of a 6-inch Portland cement foundation and asphalt 2 inches thick was 19 francs 50 cents the square metre, say 12*s.* 5*d.* the square yard, and the yearly maintenance for ten years 2 francs per square metre, or 1*s.* 4*d.* per square yard. In the Rue de Richelieu the two systems of noiseless roadways, asphalt and wood, had been laid this year side by side; a few years would prove which of the two possessed most durability.

Mr. Faija. Mr. H. FAIJA said, that as it seemed to be admitted that the life of wood pavement was dependent, to a rather important extent, on the foundation on which the wood-blocks were laid, he agreed with the Author that it was better to have good clean ballast for the formation of the concrete, than to use the broken granite which existed in the old roadway, from which it would be hardly possible to make a good concrete. Even after the granite had been screened it was very dirty, and all the holes and interstices, which for the production of concrete should be filled with cement, were filled with dirt. Then again, the screening removed not only the dirt but also the smaller pieces of stone, leaving only the large pieces, so that to secure a sound concrete a much larger quantity of cement would have to be used than was necessary with the ballast. But as this extra amount of cement was not used, the concrete was very rough, very open, and consequently neither strong nor sufficiently smooth to receive the blocks; it was therefore necessary to lay a surfacing of sand and cement on which to set the blocks. This surfacing must in time break up and become reduced to powder, for it had not a thickness sufficient to resist hard wear, nor was it homogeneous with the concrete underneath. The Author had stated the cost of the concrete at 2*s.* 3½*d.* per square yard, and it was therefore evident that if the concrete had to be relaid or materially repaired every

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seven years when the blocks were renewed, the maintenance would be considerably increased beyond the figures given in the Paper; and might probably account for the high cost of maintenance which existed in the Holborn District. In fact, the concrete should be regarded as the permanent road which might from time to time be covered with wood or other material more suitable than itself to the requirements of the traffic. The concrete to be thus permanent should be one homogeneous mass throughout, without surfacing of any kind, such a concrete as resulted from a well-proportioned aggregate properly manipulated, and he therefore was certain that in putting a well-made concrete under the wood-blocks, the Author had acted to the best advantage for his vestry. Mr. Faija.

With reference to the number of experiments of the cement which he had made for the Author, and which had been published in their entirety, he should like to say that in every case he sent his report to the Author on the completion of the seven days' test, and that therefore the extracts from these reports, which were given in the Paper, were not to be considered as defining the nature of the cement as shown by future experiments, but simply as his opinion of the cement at that date. No doubt a finer-ground cement would have been preferable, and would probably have enabled the Author to obtain the strength he required with the larger proportion of aggregate, viz., 7 to 1 instead of the $5\frac{1}{4}$ to 1 which he found it necessary to use, and would therefore have resulted in economy; otherewise the cement was of good quality and well suited to the purpose.

Mr. A. Southam observed that his experience as Surveyor for the Wandsworth Board of Works at Clapham, enabled him to confirm the Author's conclusions. In October 1880, High Street, Clapham, was paved with wood by the London Tramways Company and the Wandsworth Board. In the centre of the road were two lines of tramway; these had been previously paved with several kinds of asphalt, and all had failed; the margins of the carriageway were macadam. The tramway was paved under the direction of the engineer to the company, with plain deal blocks grouted with cement; the margins, 3,600 square yards, were laid by the Improved Wood-Paving Company for the Wandsworth Board with blocks dipped in creosote, on a bed of 6 inches of concrete, composed of Thames ballast and Portland cement, in the proportion of 6 to 1, at a cost of 11s. per square yard. The excavation was undertaken by the Wandsworth Board; the value of the macadam somewhat exceeded the cost of breaking-up, Mr Southam.

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Mr. Southam. carting and sifting it for use elsewhere. The pavement had been maintained by the Improved Wood-Paving Company free of cost for three years, when they expressed their willingness to enter into a contract to maintain it for a further period of fifteen years at 10*d.* per square yard per annum, and to leave it in good order at the end of that term; but although that was considered a small sum the Board had thought it desirable to maintain it themselves. Both the pavement laid by the Improved Wood-Paving Company and the Tramway Company were in good order, no repairs having yet been required, and the work had been done nearly four years. In any extension of wood-paving he would use plain well-seasoned yellow deal wood-blocks grouted with Portland cement, laid on concrete, formed of the old macadam, sifted and mixed with Portland cement. He considered that it was expedient to have large works executed by contract, but the maintenance should be undertaken by the parish authorities who had the control of the road.

Mr. White. Mr. G. F. White expressed his satisfaction with the Paper, which he thought was a valuable supplement to those of Mr. Deacon and Mr. Howarth. Considerable experience had been gained in the intervening five years as to the endurance of wood as a pavement. The statistics collected by the Author should help, he thought, to set at rest many questions on which opinions were divided some years back. There were two points on which he desired to offer a few remarks. The first, related to the character of the foundation to be used under the wood. The second, to the mode in which the blocks should be laid with reference to one another. It seemed now to be quite agreed that the indispensable condition of securing a good and lasting paving was a firm and unyielding foundation, and it was also conceded that no material was so fit for this purpose as concrete made of Portland cement and gravel, in the proportions of 1 part of cement to 5 or 6 parts of gravel. The Author seemed to be of opinion that a thickness of 6 inches was sufficient for all purposes. Mr. White concurred in this view where the soil under the concrete was hard and undisturbed; but where the ground had to be picked up to provide for gas or water pipes, as was so generally the case, he thought the layer of concrete should not be less than 8 to 9 inches, especially in thoroughfares where the traffic was heavy. He had noticed in certain cases, and especially in Pall Mall, where the wood paving was probably in a worse condition than in any street in London, that the excavation for the concrete base had been very unequal in depth, the sub-stratum having in some cases been hardly removed at all, while in other parts there were holes

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12 and 13 inches deep, which had been filled up with hard rubbish; and over this surface had been laid a bed of concrete, averaging hardly more than 3 inches in thickness. Such a mode of proceeding could only have one result, which had been predicted while the work was in progress, namely, the speedy breaking up of the pavement, with the consequent necessity of replacing it within a year or two. As a matter of fact that was what happened. The paving showed signs of subsidence almost immediately; and, though the middle of the roadway had been in part relaid, the generality of the work was in as bad condition as ever. The Author had mentioned two cases in which the concrete had been laid 12 inches thick, and though in the one case (Regent Street) the advantage had been nullified by the inferior quality of the wooden road laid upon it, it was to be inferred from the description of another example in Parliament Street that the life of the wood road would, in the Author's estimation, be considerably increased by the extra solidity of the deep foundation. From a careful consideration of the whole question, Mr. White had come to the conclusion (1) that the concrete should in all cases have a thickness sufficient to make it act as a beam in bridging over these inequalities of excavation. (2) That the life of the wood was in direct proportion to the immobility of the foundation, which must be deep enough to resist from the first the hammering action of horses' hoofs and the heavy pressure of wheels. The second consideration to which he would advert, was the way in which the blocks should be laid together in the roadway, and which resolved itself practically into a question of joints, or no joints. Now in the various pavings reported on by the Author every sort of jointing seemed to have been tried, and though he had judiciously abstained from dogmatically asserting his opinion, lest he should perchance be regarded as the partizan of any particular system, there seemed to be little doubt that he had a strong preference for laying the blocks together as closely as they could be put, and filling in the interstices with Portland cement grout. In this view Mr. White heartily concurred, and was glad to find it was also the opinion of Mr. Howarth.[1] He believed that the use of grooves or wide joints, as affording foothold for horses, was of very doubtful advantage, since, when the paving was perfectly dry or thoroughly wet, the foothold was complete, even with a jointless material like asphalt; and when the pavement was in the intermediate state of slipperiness, caused by frost or London fog, the grooved paving Mr. White.

[1] Minutes of Proceedings Inst. C.E., vol. lviii., p. 41.

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Mr. White. gave no more support to horses than did the close joint, the reason being that the mud filling of the joints, taken in connection with the rounded edges of the blocks, was rather a cause than a preventive of slipperiness, which was altogether absent in the case of the continuous paving. Another argument against setting the blocks apart was the fact that their being so set helped the abrasion and rounding of their arrises, which was not only in itself an element of deterioration, but tended after a time to create a sort of corduroy road, on which the wheels bumped from one block to another, producing thereby a jar very detrimental to comfort in driving over it. If any proof were needed of the correctness of this statement, one had only to drive in Oxford Street, over the road running from the Marble Arch eastward, to feel the difference in smoothness and comfort of the close-jointed pavement in comparison with the grooved and bumpy road which succeeded it further east.[1]

Mr. White had been told by omnibus drivers, who were excellent judges, that if the wide-jointed pavements were universal in London streets, there would not be a driver without a spinal complaint at the end of a twelvemonth. As regarded the direction in which the blocks should be laid in relation to the street, there would seem to be no doubt that it should be transversely to its length, like ordinary stone paving. In the paving before referred to in Pall Mall, the blocks had for some inscrutable reason been laid diagonally, than which nothing could be imagined more unsafe for horses, or more prejudicial to the comfort of those who drove over them, especially when the joints were, as in the case of one exhibited, $1\frac{1}{2}$ inch in thickness. This particular pavement appeared from the Author's statement to have been constructed at a cost of about 8*s.* per square yard, about one-half the price at which most other roads had been laid. It was in his knowledge that the expense of making it had been largely subsidized by the Clubs and the War Office, who had not taken the ordinary precaution of employing an inspector to watch its construction, but had left it entirely to the parochial authorities, of whose parsimony and ignorance it remained unhappily a convincing proof. It was to be hoped such a state of things would not easily recur, though he was not without fear that the neighbouring roadway of Cockspur Street and Charing Cross, quite recently laid, would manifest before long the consequences of insufficient foundation. This led him to enquire whether it was impossible to institute some more authoritative control than at present existed over the

[1] Since this was written the road has been renewed.—G. F. W.

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construction of the wood roads of London. The information Mr. White. gathered by Mr. Howarth and by Mr. Stayton was as ample and specific as would have been collected by a select Committee sitting on the question, and must surely therefore be sufficient as a guide to some uniform plan for the execution of such works. The question then became whether such uniformity could be enforced on the different parochial bodies of the Metropolis. The roadways were for the comfort of the whole community—not of individual parishes; and he could heartily wish that such a body as the Metropolitan Board of Works, which seemed to have most things under its management, could actively intervene to give the ratepayers the benefit of the investigations which had been made on the subject, instead of leaving them any longer to be the victims, both in pocket and in comfort, of every experimenter who might have a nostrum to recommend, or a patent to push.

Mr. Stayton, in reply to the correspondence, remarked that such Mr. Stayton. observations as those made by Mr. Culverwell were extremely practical and valuable. He, however, felt compelled to reassert his opinion that the pitch-pine blocks in King's Road created an unpleasant "jarring" motion when driving over them. He had many times experienced it, and on a recent occasion the effect was very apparent. Possibly this evil could be mitigated by the application of Henson's felt bed and joint. He was glad that Mr. Culverwell had so clearly expressed his reasons for declining to support the creosote theory, feeling convinced that the extra cost of creosoting could be better expended in the selection of the timber. He concurred in Mr. Delano's objection to the terms "asphalt" and "asphaltic" as applied to the wood pavement laid by the Asphaltic Wood-Pavement Company; obviously the British asphalt used by them was a manufactured article, and the name might lead to confusion. Where the word "asphaltic" appeared in Tables III. to VII., it merely referred to the "Asphaltic" Company's system, in the same way that "Henson's" or the "Improved" systems had been referred to. He did not find the wood in Chelsea "produce poisonous emanations under a hot sun," although it had been laid five and a-half years; this fact, however, could be accounted for, because its surface was thoroughly watered and machine-swept twice a week during the summer, independently of the attention described under the heading of management (p. 30). Any neglect of this service, however, would soon create the unpleasant condition described. He assumed that it would be taken for granted that the thickness of concrete foundation referred to by Mr. White (6 inches) would only be adopted where the soil

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Mr. Stayton. was hard and undisturbed, and he could refer to numerous instances in the Chelsea pavements where the thickness was from 8 to 10 inches; in fact, a depth of 12 inches had been laid for a long distance over the site of a suspicious gas trench in Sloane Street.

During the evening some specimens of "teredo," commonly called "cobra" in the Colony, sent as a present to the Institution by Mr. J. B. Stanley, Assoc. M. Inst. C.E., of the Harbours and Rivers Department, Brisbane, were exhibited. The specimens consisted of the worm in spirits, the head of a worm, and a piece of a pile showing the effect of the working of the worm. The specimens of the worm and head were taken from an unmetalled ironbark pile, which had not been in the water more than eighteen months, and was one of the piles used in the cofferdam at the entrance to the graving dock in the Brisbane River. The piece of the pile was from the same place, and had not been more than two years in the water. The Brisbane River at the "dock" was always quite salt. Mr. Stanley had been informed on the authority of two reliable persons that a worm 14 feet long had been taken out of a plank from a ship's bottom in the port of Brisbane.

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29 May, 1884.

The Session was concluded by a Conversazione, which was given by the President and Lady Bazalgette at the South Kensington Museum, by permission of the Lords of the Committee of the Council of Education.

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SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 2010.*)

"On the Area of Sluice-Opening necessary for the Supply-Sluice of a Tidal Canal."

By JAMES HENRY APJOHN, M.A., M. Inst. C.E.

IN the tidal canals hitherto constructed in Bengal, the filling has been effected during high tides, and through the locks, the gates of which opening towards the canal admit the river-water, when the tide rises higher than the water impounded in the canal. But in the case of the coast-canal, now under construction, the locks have reverse gates on the river side for the exclusion of the tide, the filling being effected through sluices, between which and the canal are channels, from 1 mile to 2 miles in length; this arrangement is adopted in order that all the silt, which comes in with the tidal water, may be deposited before it reaches the canal proper. Now, it is evident that the size of sluice required will depend on the surface area of the canal, on the depth of the filling-up necessary in one tide, and on the rise of tide during the high water above canal water level. The Author tried for a long time, with the help of Mr. Maconchy, Assistant Engineer, to solve the problem mathematically, and also corresponded with Professor Unwin on the subject, who kindly gave a solution, which, perfect in every other respect, failed to determine what the loss of head would be, during filling, by the rising of the water surface on the canal side of the sluice; not the rise due to the filling-up, but that of the wave which forms for the distribution of the inflow to the distant parts of the canal; in fact the problem was one in hydrodynamics for the solution of which there were no data. The Author therefore determined to have some careful observations taken on the Second Range of the Hidgillee tidal canal, which is 17 miles in length.

The points to be determined were:—

1st. How much did the water in the river rise above that in the canal during filling?

2nd. What was the rise in the canal due to the formation of the wave?

3rd. In what way did the water taken in through the lock raise the whole surface of the canal?

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In order to determine these points, four gauges were erected, one outside the Kalinagar lock, in the channel between it and the Russulpore river, a second in the canal just inside the lock, a third 8 miles down the reach, and the fourth in the canal close to the Teropekia lock, on the Haldi river, which lock has its gates strutted against high tides, so that the Haldi water never enters the canal, which is supplied entirely from the other end. All these gauge-readings were taken during every quarter-hour of the day and night, while the spring tides were filling the canal, from the 28th December to the 1st January last, and again from the 9th to 13th February. The great difficulty is of course to get the gauges read correctly, especially as the filling occurs only during the high night tides. However, by having two readers at each gauge, who relieved each other every four hours, and offering a small bonus for good work, trustworthy readings were obtained, as is proved by the truth of the plotted curves, which would certainly have shown it, if there had been carelessness in the observations. Any variation that occurred in the several watches was allowed for when plotting the curves, as each gauge-reader recorded daily the time of sunrise and sunset as observed by him. The results of these gauge-readings are shown in the curves Figs. 1, 2, and 3, Plate 11. The great irregularity in the canal level, shown in the first series, is due to an attempt to get more striking curves by lowering the canal as much as possible between each filling, the lock valves at either end of the reach being kept open for this purpose. The object was attained as far as comparing the total rise of the river above the canal-level with the effective head on the lock, but the curves were spoilt for studying the wave-action in the canal. The second series of observations, made in February, gave very satisfactory results in the latter respect. Some observations were also made at the Gewakhally lock, through which the first range, 10 miles in length, is filled; these readings were only taken on the river and canal side of the lock, no gauge being observed at the middle or other end of the range.

From an inspection of these curves, it will be at once seen, that as the river rises above the canal, the latter also rises, thus largely reducing the head available for forcing the water through the lock, and if any relation could be found between the two rises, the purpose for which the readings were taken would be attained; so, for convenience of reference, nine curves from the two series of experiments made at Kalinagar, have been collected in Fig. 4, Plate 11, and also in the same Fig. nine curves obtained at Gewakhally on the first range. In the following Table has been entered,

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for each of these eighteen curves, the ratio of the total rise of the river above the canal, to the difference between the total rise of the former and the temporary rise of the latter.

—	a.	$a + b$.	$\frac{a}{a+b}$.	Remarks.
First series, Kalinagar.	0·23	2·00	0·12	0·23 = mean ratio for the whole eighteen observations.
	0·52	2·22	0·23	
	0·59	2·19	0·27	
	0·19	1·04	0·18	
	0·59	2·20	0·27	
Second series, Kalinagar.	0·19	1·09	0·17	0·25 = mean ratio for the second series at Kalinagar, and for the whole number at that place, excluding the first, which is only half the mean.
	0·33	1·23	0·27	
	0·35	1·25	0·28	
	0·24	0·79	0·30	
Gewakhally.	0·25	1·00	0·25	0·23 = mean ratio for all the Gewakhally experiments.
	0·20	0·92	0·22	
	0·15	0·75	0·20	
	0·10	0·45	0·22	
	0·20	0·85	0·24	
	0·20	0·85	0·24	
	0·30	1·20	0·25	
	0·15	0·90	0·18	
	0·20	0·87	0·23	

These ratios, obtained from gauge-readings subject to some error of observation, are remarkably uniform, as in every case except the first, the addition or subtraction of 0·05 to or from the gauge-readings brings the ratio to the mean, and the great discrepancy in the first case, where the effective head is only 0·12 of the total rise (or half the average) is doubtless caused by (as will be seen in the longitudinal section, Plate 11, Fig. 5) the canal water being so low that the silt-bar, in the first 2 miles of the range, was almost dry, and so offered much resistance to the propagation of the wave over it, causing the reduction of the effective head in consequence of the necessary increase in height of wave. The canal-level being higher during subsequent fillings, the resistance of the shoal was less, and the normal ratio was attained, which is doubtless a function of the hydraulic mean depth of the canal and sectional area of the lock waterway; it may be observed that in the second series, the effective head gradually increased as the level of the canal rose. In the calculations below, the effective head will be taken at 0·25 of the total rise. The large scale curve A in Fig. 4 is an average of the Kalinagar curves in Fig. 4. It will be observed that it is as nearly as possible a true parabola, and the

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curve within representing the canal rise is also a parabola with the same axis; if any line, therefore, be drawn parallel to the axis and cutting both curves, the portion a' will have the same ratio to b' that a bears to b, but this ratio has been found by experiment to be 1 to 4; there are now, therefore, materials available for calculation of the effective head during the whole time that the canal is being filled.

Mr. Maconchy has lately succeeded in working out theoretically the ratio experimentally determined as above, and there is a most remarkable agreement between the two; his note on the subject is appended. He also worked out, from the data in Figs. 1 to 3, the curves shown on Fig. 5, representing the surface of the canal at intervals of half-an-hour during filling. From these curves it is seen that the raising of the canal level is effected by a wave, with a velocity of about 8 miles an hour,[1] and it is evident that the length of the canal does not in any way affect the head on the lock, unless it should be so short that the return wave would reach the lock before the conclusion of the filling.

The practical calculation of the area of sluice opening required for a supply sluice may now be proceeded with. The height through which the canal is raised, by actual filling up in one tide, is so small in practice compared with the rise due to the wave, that it may be neglected, and farther on it will be shown that in the case of Range III. of the coast canal, for which it is desired to find the area of the supply-sluice, the mean daily highest rise of the tide above the canal during filling will be 1·92 foot, and reference to the curve A on Fig. 4 gives three hours as the duration of the tide with such a rise. In the following Table, with a view to determine the ratio that the mean velocity during the whole time of filling bears to the maximum, the square root of the effective head (to which the velocity through the sluice is proportional) has been calculated at the beginning and at the end of each quarter-of-an-hour; the arithmetical mean of all these, divided by the number of quarter-hours will be sufficient approximation to the truth.

It has thus been found that the mean velocity during the whole

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[1] It is known that the velocity of propagation of a wave of translation is the velocity due to half the depth of water measured to the wave-crest. Taking the depth of water in the canal to average 7 feet measured to the wave-crest, the velocity of the wave would be $8 \cdot 02 \sqrt{3 \cdot 5} = 15$ feet per second, or 10 miles per hour. The difference between this and the observed velocity given above may be due to friction and obstructions in the canal. But the agreement is close enough to be of interest.—W. C. U.

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time of filling will be three-fourths of the maximum velocity, but the maximum velocity through the sluice is that due to one-fourth of the total rise of the tide above the canal.

Time.	h.	$0\cdot25\ h$.	$\sqrt{0\cdot25\ h}$.	Mean.	Proportion of Mean to Maximum.
H. M.					
0 00	0·00	0·00	0·00		
0 15	0·50	0·12	0·35		
0 30	0·93	0·23	0·48		
0 45	1·26	0·31	0·56		
1 00	1·50	0·38	0·61		
1 15	1·73	0·43	0·66		
1 30	1·90	0·48	0·70	0·50	0·75
1 45	1·86	0·46	0·67		
2 00	1·63	0·41	0·64		
2 15	1·33	0·33	0·57		
2 30	1·95	0·24	0·50		
2 45	0·50	0·12	0·35		
3 00	0·00	0·00	0·00		

h = total rise of tide above canal level.

$$\text{Max. V} = k\sqrt{0\cdot25\ h};$$

$$\text{Mean V} = \tfrac{3}{4}k\sqrt{0\cdot25\ h}$$

$$= \tfrac{3}{8}k\sqrt{h}.$$

The final solution of the problem can now be undertaken.

The total length of the third range of the coast canal is, with the canalized Surpai and Contai nullah, which forms part of it, about 42 miles, and the superficial water-area is twenty millions of square feet. On Fig. 6 is given a diagram, showing the high and low water for all the tides of the month of December (the lowest in the year) in the Russulpore river, and on it is drawn the maximum canal-level, which for reasons that need not be here entered upon, has been fixed at 109·5. To calculate the lowering that will occur during the days that high water in the river is below canal-level, the same data adopted originally by Mr. Vertannes will be used, viz., that in each twenty-four hours there will be forty lockages at each end, and a loss from leakage through the lock valves and gates of 2 cubic feet per second at each lock, or 4 cubic feet per second in all; also a loss from evaporation of one-sixth of an inch, or 0·014 of a foot per diem. A preliminary calculation shows that the canal will lose about 1 foot during neaps, therefore the mean canal-level will be 109·00.

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Mean-tide at Russulpore is 103·20, and at the other end in the Śuburnarekha it is 104·5, and the lock-chambers being 150 × 20, the total loss from lockage will be:—

$$(109 \cdot 0 - 103 \cdot 2) + (109 \cdot 0 - 104 \cdot 5) \times 150 \times 20 \times 40$$
$$- (5 \cdot 8 + 4 \cdot 5) \times 3{,}000 \times 40$$
$$= 1{,}236{,}000 \text{ cubic feet for lockage.}$$

Add 345,600 cubic feet for leakage,

1,581,600 cubic feet total for lockage and leakage.

Divide the above by 20 millions, and the quotient = 0·079 = daily fall of level for lockage and leakage.

Add for evaporation	0·014
Total daily lowering	0·093

But it is seen from the tidal diagram that between springs there are nine days, during which the tide will not reach the canal-level, therefore the total lowering will be 0·093 × 9 = 0·837 foot, and during the following seven days seven night tides rise above the canal (neglecting as insignificant the first night tide and the day tides, which rise very little higher than the canal), therefore to fill up the canal to full level each tide must on an average raise it $\frac{0 \cdot 837}{7} = 0 \cdot 119$. The lowering due to lockage, &c., for the day preceding the filling has of course to be added, as between each filling the canal is again lowered by this amount, the total height through which each tide must raise the canal-level will accordingly be 0·119 + 0·093 = 0·212.

The above height through which the canal must be raised each tide, multiplied by the superficial area, will give the cubic feet of water required; but already the mean velocity through the sluice has been ascertained, and the area of one vent being given, the number of vents required can at once be determined.

Let a = area of one vent;
A = superficial area of the canal;
h = total rise of tide above the canal-level;
f = height through which the canal is to be lifted;
S = number of seconds of time that the tide is above the canal;

k = constant in the "velocity through sluice" formula $v = k\sqrt{h}$;

n = number of vents required; then

$$n = \frac{8 f A}{3 a S k \sqrt{h}}.$$

It only now remains to ascertain the mean rise of the tide above the canal, which is done from the diagram, according to the following Table:—

Maximum Tide Level.	Canal Level.	Rise of Tide above Canal.	Mean Rise of Tide above Canal.
110·40	108·66	1·74	
111·02	108·78	2·24	
111·19	108·90	2·29	
111·40	109·02	2·38	1·92
111·19	109·14	2·05	
111·02	109·26	1·76	
110·40	109·38	1·02	

All values are now determined, and are:—

$a = 22{\cdot}5$;
$A = 20{,}000{,}000$;
$h = 1{\cdot}92$;
$f = 0{\cdot}212$;
$S = 10{,}800$ (seconds in three hours);
$k = 5$ (lowest coefficient);

$$n = \frac{8 \times 0{\cdot}212 \times 20{,}000{,}000}{3 \times 22{\cdot}5 \times 10{,}800 \times 5\sqrt{1{\cdot}92}}$$

$= 7{\cdot}25$, number of vents required.

One of the elements of the above calculation may be objected to, viz., the height of the Russulpore tide during the lowest month, which has been taken at 111·40, or that observed on the night of the greatest rise; this was what was actually observed last December, and that it was not an exceptionally high tide is shown as follows:—Since November, 1881, a daily record has been kept of the level of the tidal canal, and it has been found that 110·6 is the lowest to which the canal ever filled up during springs, but the second series of observations shows the greatest rise of the tide to have been 0·7 higher than the level to which the canal was filled during the same springs; this added to 110·6 gives 111·3 as

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the greatest rise of the lowest springs since November, 1881, or a difference of only 0·1 from the highest tide observed last December. Gauge readings as a rule only show day tides, which are during December 1½ foot lower in the Russulpore than the night ones. It has thus been determined that seven and a quarter vents of 22·5 square feet each will, during the lowest springs of the year, be sufficient to fill the canal to the desired level; and it must be remembered that in determining the velocity through the sluice the very small coefficient 5 has been used, whereas 7·25 would be probably nearer the truth for such large vents, subject to so small a head, the use of which coefficient would reduce the vents to 5. However, to provide against any possibility of the sluice proving too small, in the event of the channel between it and the canal being at any time much silted, it is proposed to allow ten vents to the sluice; twenty vents were originally provided, but at the time that Mr. Vertannes made this calculation it was proposed to have the maximum water-level 0·5 foot higher, and the extra rise of the Russulpore night tides was not allowed for.

In the three other ranges of the canal, the supply-sluices serve also as outlet-sluices, and their ventage has been fixed according to drainage requirements. It is only needful, therefore, to show that the ventage so provided is sufficient to raise the canal to the required level during the lowest springs of the year.

In Range IV. A, the water-surface area is eight millions of superficial feet, and there are ten vents allowed to the sluice. The tides for December of the Sartha (the river on which the sluice is situated) are shown on Fig. 6. Using these data and the formula already determined, it will be found that this reach will fill up to about 110·00 and fall to 108·00, but when designed it was thought that the water in canal would not rise to within a foot of the above, so the ventage allowed is more than ample.

Range IV. B, is very short (6 miles), and the water surface only two and a half millions of superficial feet; therefore the lowering per diem is great, being as rapid as the daily decrease in height of tides from springs to neaps. The canal will accordingly fall during neaps to level of lowest high water, or to 106·00; with the ten vents allowed the canal will rise to within 0·70 of the highest tide, or to 109·50.

Range V. This range, 38 miles in length, has a water area of seventeen millions of superficial feet, and twenty-two vents are allowed, the maximum level will be 109·7, and minimum 108·5; the tides of the Jamka and Kansleaus nullahs, on which the sluices are situated being similar to those in the Burabullung;

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the same curves are used for both Ranges IV. A, and V. The most convenient form of the formula for determining the rise with a given number of vents, is

$$s\sqrt{h} = \frac{8 f A}{3 a n k}.$$

To facilitate calculation a short Table is given below, showing the values of $S\sqrt{h}$ for all those of h from 0·1 to 2·0. It will be observed that as h increases in arithmetical progression, $S\sqrt{h}$ very nearly follows the same rule, so if the rise of tide above canal be doubled, the consequent filling up of the canal will also be doubled.

h.	S.	$S\sqrt{h}$.	h.	S.	$S\sqrt{h}$.
0·1	1,800	558	1·1	7,740	8,127
0·2	2,592	1,158	1·2	8,280	9,108
0·3	3,420	1,846	1·3	8,640	9,874
0·4	4,140	2,608	1·4	9,000	10,800
0·5	4,800	3,360	1·5	9,360	11,420
0·6	5,400	4,158	1·6	9,720	12,344
0·7	5,940	4,989	1·7	10,080	13,102
0·8	6,480	5,832	1·8	10,448	13,930
0·9	6,840	6,498	1·9	10,620	14,655
1·0	7,380	7,380	2·0	11,000	15,510

The communication is accompanied by seven sheets of diagrams, which have been reduced and engraved as Plate 11.

[APPENDIX.

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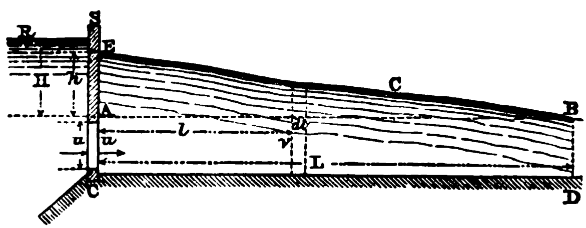
APPENDIX.

NOTE BY G. C. MACONCHY, ASSISTANT ENGINEER.

DISCHARGE from a tidal river into a canal through a sluice.

FIG. 1.



R is the tidal river, C the canal, S the sluice, A B initial surface of canal, previous to rise of tide. The sluice is self-acting, so as to retain the water in the canal when the tide level is below canal level, and to admit water when tide level rises above canal level.

Let w = area of cross section of canal.
w' = „ „ „ of sluice.
m = hydraulic mean depth of canal.

Since the rise of surface is small compared with the depth, m and w are taken as constant quantities.

d = depth of canal.
ζ = coefficient of friction.
L = distance to which wave of inflow has penetrated in time t.
v = velocity along canal at a cross section distant l feet from sluice.
u = velocity along canal at a cross section just inside sluice.
u' = velocity through sluice.
k = velocity coefficient.
H = rise of tide above original canal level in time t.

Then, effective head = H − h

and $$u' = k\sqrt{2g(\mathrm{H} - h)};$$

but $$u = \frac{w'}{w}u',$$

therefore $$u = \frac{w'}{w}k\sqrt{2g(\mathrm{H} - h)} = k'\sqrt{2g(\mathrm{H} - h)},$$

where $$k' = \frac{w'}{w}k.$$

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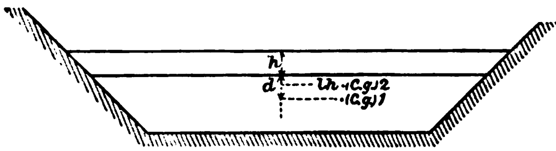
let d' = depth of centre of gravity of cross section below surface at far end, then depth of centre of gravity at the sluice end is, $d_o = d' + h - a\,h$.

Fig. 2.



a is a constant depending on the dimensions of canal, and is given by the expression—

$$a = \pm \frac{\sqrt{\{B + r\,(d + h)\}^2 + r^2\,(d + h)^2} \mp \sqrt{(B + r\,d)^2 + r^2\,d^2}}{2\,r\,h},$$

where $\begin{cases} B = \text{bottom-breadth of canal.} \\ r = \text{ratio of side slopes to 1.} \\ d = \text{depth of water.} \\ h = \text{rise of surface at sluice end.} \end{cases}$

In practice, a does not vary much from its mean value (0·6), and may be taken as constantly equal to 0·6 in all ordinary cases.

Now, the forces acting to change the momentum of the mass E B D C (Fig. 1) are—

(1) Pressure on ends.
(2) Friction against bottom and sides.

Resultant pressure on ends—

$$= G\,w\,(h + d' - a\,h) - G\,w\,d'$$

$$= G\,w\,h\,(1 - a).$$

$$\text{Resistance of friction} = -\frac{\zeta\,G\,w}{2\,g\,m}\int_o^L v^2\,dl.$$

Momentum entering mass in unit time—

$$= \frac{G\,w}{g}\,u^2$$

momentum leaving $= o$.

Therefore change of momentum in unit time—

$$= +\frac{G\,w}{g}\,u^2.$$

Equating impulse of forces in unit time to change of momentum.

$$\frac{u^2}{g} = h\,(1 - a) - \frac{\zeta}{2\,g\,m}\int_o^L v^2\,d\,l \quad . \quad . \quad . \quad . \quad (1)$$

Equation (1) cannot be further elucidated without obtaining some other relation between v and z.

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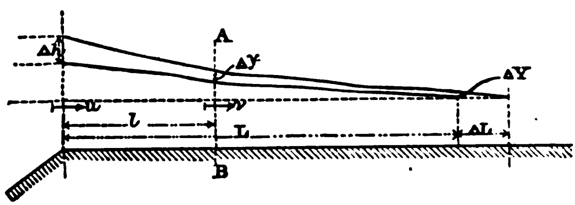
Three different assumptions can be made regarding the manner in which the canal surface rises, each of which gives a simple relation between v and z.

Let Δh = rise of canal-surface just inside sluice in a short time Δt.
Δy = rise of surface in the same time at a cross section distant z feet from sluice.
ΔY = rise of surface in the same time at the extreme point to which the flow has penetrated.

Then the assumptions are—

Fig. 3. ΔY is negligible compared with Δh, and Δy varies as $(L - z)$.
Fig. 4. Δy is constant and equal to Δh throughout the length L.
Fig. 5. Δh is negligible compared with ΔY, and Δy varies at z.

Fig. 3.



In the first case, the quantity of water admitted to the canal during time Δt is equal to the area of a triangle of base Δh and height L, multiplied by top breadth of canal.

Let Q = discharge past sluice in time Δt.
q = discharge past A B.
B = top breadth of canal.

Then
$$Q = B\frac{L\,\Delta h}{2} = w \cdot u \cdot \Delta t,$$

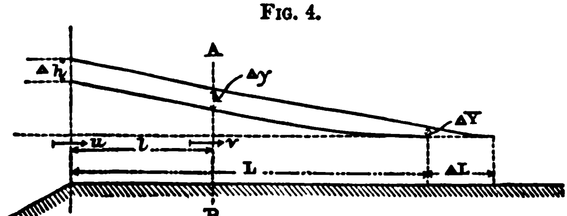
and
$$q = B\frac{(L - l)\,\Delta y}{2} = B\frac{L - l}{2}\,\frac{L - l}{L}\,\Delta h$$
$$= w\,v\,\Delta t.$$

Hence
$$\frac{v}{u} = \left(\frac{L - l}{L}\right)^2,$$

therefore
$$\frac{d\,v}{d\,l} = -\frac{2}{L}\sqrt{u\,v},$$

therefore
$$\int^{L} v^2\,d\,l = \frac{L\,u^2}{5} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (I.)$$

Fig. 4.



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In the second case—

$$Q = B\,L\,\Delta h = w\,u\,\Delta t$$

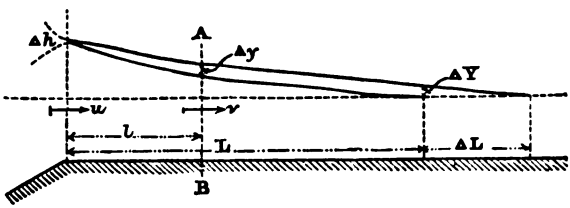
$$q = B\,(L - l)\,\Delta h = w\,v\,\Delta t,$$

therefore $$\frac{u}{v} = \frac{L - l}{L},$$

therefore $$\frac{d\,v}{d\,l} = -\frac{u}{L},$$

therefore $$\int_0^L v^2\,d\,l = \frac{L\,u^2}{3} \;.\;.\;.\;.\;.\;.\;.\;.\;.\; \text{(II.)}$$

FIG. 5.



In the third case—

$$Q = B\,\frac{L\,\Delta\,Y}{2} = w\,u\,\Delta\,t$$

$$q = B\,\frac{L\,\Delta\,Y - l\,\Delta\,y}{2} = B\,\frac{\Delta\,Y}{2}\left(L - \frac{l^2}{L}\right)$$

$$= \frac{B\,\Delta\,Y}{2}\,\frac{L^2 - l^2}{L} = w\,v\,\Delta\,t,$$

therefore $$\frac{v}{u} = \frac{L^2 - l^2}{L^2},$$

therefore $$\frac{d\,v}{d\,l} = -\frac{2}{L}\sqrt{u\,(u - v)},$$

therefore $$\int_0^L v^2\,d\,l = \frac{8}{15}\,L\,u^2 \;.\;.\;.\;.\;.\;.\;.\;.\;.\; \text{(III.)}$$

The results given by these three assumptions are seen to be all of the same form, and can be expressed generally thus:—

$$\int_0^L v^2\,d\,l = \frac{2}{R}\,L\,u^2$$

where $$R = \begin{cases} 10 \;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\; & \text{I.} \\ 6 \;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\; & \text{II.} \\ 3{\cdot}75 \;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\; & \text{III.} \end{cases}$$

The truth will obviously lie somewhere between the extremes of assumptions I. and III. Experiment shows that (I.) is nearest the truth during rise, and (II.) during fall of tide, (III.) during a stationary head.

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By these assumptions—

$$\int^{L} v^2\, d\,l = \frac{2}{R}\, L\, u^2$$

substitute in equation (1).

Then $$\frac{u^2}{g} = h\,(1 - a) - \frac{\zeta}{g\,m\,R}\, L\, u^2 \quad . \quad . \quad . \quad . \quad (2.)$$

now $$u^2 = 2\,g\,k^2\,(H - h),$$

put $$H - h = \rho\, H.$$

Then $$h = H\,(1 - \rho),$$

and $$u^2 = 2\,g\,k^2\,\rho\, H$$

substitute in equation (2).

Then $$2\,k^2\,\rho\, H = H\,(1 - \rho)\,(1 - a) - \frac{\zeta}{g\,m\,R}\, L \cdot 2\,g\,k^2\,\rho\, H.$$

Hence $$\rho = \frac{(1 - a)\, m\, R}{(1 - a + 2\,k^2)\, m\, R + 2\,\zeta\, k^2\, L}.$$

If d = depth of canal,

and V = velocity of translation of wave of inflow,

then $$V^2 = g\, d,$$

and $$L = V\, t = t\,\sqrt{g\,d},$$

therefore $$\rho = \frac{(1 - a)\, m\, R}{(1 - a + 2\,k^2)\, m\, R + 2\,\zeta\, k^2\,\sqrt{g\,d}\;\, t}.$$

That is— $$\rho = \frac{A}{B + C\,t}.$$

where $$A = (1 - a)\, m\, R$$

$$B = (1 - a + 2\,R^2)\, m\, R$$

$$C = 2\,\zeta\, k^2\,\sqrt{g\,d}.$$

The formula must be used with the reservation that the term C t must not exceed $2\,\zeta\, k^2\, L_1$, where L_1 is the total length of canal in feet.

The constants in the following results are taken as nearly as possible equal to those which obtained in the experiments on the tidal canal.

$a = 0{\cdot}6$
$k = 0{\cdot}3$
$m = 5{\cdot}45$
$d = 5{\cdot}5$ (this is the depth got by substituting the actual observed velocity in the equation $v^2 = g\,d$) $\zeta = 0{\cdot}0075$.

I. For rising tide—

$$R = 10$$

$$\rho = \frac{21{\cdot}8}{31{\cdot}6 + 0{\cdot}018\, t}.$$

$t =$	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	hours {In two hours the wave had reached end of canal.
$\rho =$	0·68	0·34	0·22	0·17	0·14	{So all subsequent values of ρ are = 0·14.

II. For falling tide—

$$R = 6$$

$$\rho = \frac{13 \cdot 1}{18 \cdot 9 + 0 \cdot 018\, t}.$$

$t =$	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	hours.
$\rho =$	0·68	0·25	0·16	0·11	0·09	..

III. Constant head—

$$R = 3 \cdot 75$$

$$\rho = \frac{8 \cdot 2}{11 \cdot 8 + 0 \cdot 018\, t}.$$

$t =$	0	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	hours.
$\rho =$	0·68	0·19	0·11	0·08	0·06	..

The expression given, the value of ρ can be put in the following form—

$$\rho = \frac{(1 - a)\,\frac{1}{R^2}}{\left(1 + a + 2\,k^2\right)\frac{1}{R^2} + \frac{3\,L}{m\,R}}.$$

It will be seen that the numerator and first term of the denominator express the effect which the resistance caused by the inertia of the water has on the effective head. The second term of the denominator expresses the effect of the resistance caused by friction on the effective head.

At the beginning of the flow when—

$$L = o,\ \rho = \frac{1 - a}{1 - a + 2\,k^2}.$$

This is also the value of ρ for a frictionless channel. As the flow continues, the wave travels along the canal, and a longer length is exposed to the action of friction. Hence the resistance caused by friction is increased, and the effective head diminished. In the formula, this effect is shown by L being increased and consequently ρ diminished.

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(*Paper No. 2008.*)

"The New Harbour of Trieste."

By FRIEDRICH BÖMCHES.

Translated by JAMES RANSON BAASS, Stud. Inst. C.E.

THE old roadstead of Trieste was for years totally inadequate to satisfy the requirements of modern navigation. All the provision it afforded for harbouring vessels consisted of a few sheltered docks, which were of varying and insufficient depth, one or two quays, a pier or two, and finally a railway station, situated some 23 feet above the level of the quays, and not in communication with them.

The Government determined to better this state of things, and decided to convert the old roadstead into a safe and perfectly-equipped harbour, in order to enable Trieste to compete successfully with the modern seaports of Europe.

Of the large number of plans proposed, that illustrated on Plate 12 was selected. It will be seen that the improvements embraced the north-eastern half of the roadstead, and comprised the construction of three spacious docks; the first two being protected from the effect of storms by a breakwater running parallel to the shore, whilst the third, intended for vessels laden with petroleum and other inflammable articles, should be enclosed on all sides. An essential element in the scheme consisted in the diversion of the two streams, Martesin and Klutsch, which formerly flowed into that portion of the roadstead now occupied by the docks. It also included the construction of a new railway station, as well as the equipment of the docks with the apparatus and buildings required for the accommodation of the traffic. The latter works were only begun after a certain stage had been reached in the construction of the actual harbour, which was so delayed by the unfavourable nature of the ground, and the settlements arising therefrom, that the time taken to finish the work amounted to twice what had been estimated. It appeared desirable, therefore, in the interests of commerce, to hand over to the Government the several portions of the work on their

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completion, after they had been inspected by the maritime authorities.

The dates at which the different works were so delivered are as follows:—

The breakwater	in 1874
„ first dock	„ 1876
„ second dock	„ 1879
„ third dock (petroleum-dock)	„ 1882
„ Martesin Drain	„ 1875 and 1883
„ Klutsch „	„ 1880

The engineer appointed by the maritime authorities in Trieste to inspect the work was Mr. Carl Jäger. The work was carried out by the Southern Railway of Austria, for whom Mr. Hilaire Pascal acted as consulting engineer from the commencement until 1876. The work, which was begun in 1868, under the supervision of Mr. Ernst Pontzen, was taken over in the next year by the Author, who had charge of it to its completion, which occupied sixteen years, and cost £1,460,000. The new station and the equipment of the harbour were executed at a cost of £200,000.

Construction.

The works of which the harbour consists are, the breakwater, Docks I. and II., the petroleum-dock, and finally the Klutsch and Martesin drains (Plate 12, Figs. 1 and 2). The quay- and pier-walls, which rest on loose rubble-stone foundations, are built to the sea-level of concrete blocks, weighing 25 tons each; the upper portion of the walls above the sea-level consists of limestone, set in mortar made with hydraulic lime imported from France. This method of construction, employed to advantage in many foreign harbours, was attended with great difficulties at Trieste, on account of the presence of a considerable extent of mud bottom, between 60 and 70 feet in depth. In spite of all precautions, several of the walls were observed to settle unequally, and their reconstruction (Plate 12, Figs. 12–15), as well as the deepening of the basins, became matters of necessity. These two operations are among the most difficult that the hydraulic engineer has to perform, and have perhaps never before been undertaken under more unfavourable circumstances. The combined application of steam-cranes, diving-apparatus, and dredgers was required on a very extended scale, and the work was thereby not only increased in difficulty, but also considerably delayed.

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The two operations necessitated by the unfavourable nature of the ground form the chief feature in the Trieste harbour-works. They were not required to be undertaken in the case of Marseilles, where the sea-bed, consisting of sand and rock, produced no evil effect on the wall other than that caused by the inevitable settlement of the loose rubble foundations. In the construction of the quay- and pier-walls it was found that the section (similar to that adopted at Marseilles) selected by the Government required considerable remodelling. These alterations involved a large addition to the rubble base, and a change in the nature of the work, and in the method of carrying it out. These precautions, which were taken in the construction of the two large docks, were also observed in the case of the petroleum-dock, despite the much smaller dimensions of the pier by which it is enclosed, and the fact of the foundations having been well dredged before the rubble limestone was tipped.

The reconstruction of the concrete-block walls was very laborious, and consisted in excavating, dredging, pulling down, and re-erecting many of them, and eventually shoring all. For this work divers and steam-dredgers were extensively employed. After completing the reconstruction to water-level, the walls were carefully watched during the space of a year, and if no settlement then occurred, the work above sea-level was proceeded with.

The work of reconstruction amounted to

81	per cent. of length of quays	in Pier I.
95	,, ,, ,,	,, ,, II.
63	,, ,, ,,	,, ,, III.
131	,, ,, ,,	,, Quay I.
110	,, ,, ,,	,, ,, II.
100	,, ,, ,,	,, Petroleum-dock.

In carrying out the above works, the quantities were:—

	Cubic yards.
Earthwork	4,238,000
Loose rubble in foundations	1,820,000
Concrete-block walls	138,710
Masonry walls	45,500
Dredging of foundations	542,000
,, for deepening basins	1,014,000

These figures do not include the diversion of the Klutsch and Martesin Streams. As the new course of these is for the greater part through favourable ground, the execution of the diversions was attended with no particular difficulty.

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Equipment.

The works in connection with the equipment of the harbour could not be begun before the completion of the two large basins and the new railway station, as the greater portion of the latter is situated on the made ground lying to the rear of the docks. The works in the new station embrace lowering the old station-yard 23 feet, the construction of buildings for the accommodation of passengers and goods, and of engine-sheds and shops. The large warehouses and stores belonging to the old station were alone retained.

Immediately after the completion of the new station in 1878, a start was made with the equipment of the harbour. This comprises, besides landing-stages and mooring-arrangements, apparatus of every description for loading, transporting and storing goods — such as cranes, roads, sheds and warehouses, to the requisite extent for satisfying the demands of the traffic. The arrangement and distribution of these apparatus are shown on Plate 12, Figs. 3–11. It is, however, to be remarked that the equipment of the harbour has been confined for the present to one-third of the amount arranged for ultimately; and the completion of the remainder has been postponed in order to judge of the behaviour of the existing portion, as well as on account of the proposed abolition of the free port.

The following Table shows the capacity of the new harbour, and the present state of its equipment :—

Length of quays (excluding breakwater) . .	3,330 lineal yards.
Water-area of 3 docks	87·8 acres.
Depth of water in docks	27·7 to 42·6 feet.
Wharves	66 acres.
Six warehouses with an area of	27,002 square yards.
Two goods-sheds	3,227 " "
Steam-cranes to lift from 1½ to 3 tons . . .	6
Mooring-stages of screw-piles in first and second basins	13
Capacity of harbour	1,517,000 tons.

Of the above, Docks I. and II. serve for vessels laden with general cargo, whilst Dock III. is used for petroleum and other inflammable materials. The construction of this dock was justified by the great impetus given to the petroleum-traffic in Trieste of late years. In 1870 this traffic amounted to 11,000 tons, increasing in 1881 to 55,000 (five-hundred per cent. in fourteen years) although it is true that in 1882 it again fell, and kept on

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doing so in the following year until it amounted to only 25,000 tons. It remains to be seen whether the trade in this article will again increase, and when this will occur. In any case it appears desirable to have a special dock for the accommodation of the large number of vessels laden with other inflammable articles, such as ammunition, powder and other explosives, as well as spirit, oil, &c. The petroleum-dock possesses the normal depth of water (28 feet) so that it can also if necessary be used for large vessels carrying general cargo.

Traffic.

The protection of the roadsteads against the prevailing winds, sufficient mooring places, the necessary depth of water along the quay walls to allow of direct communication between the vessel and the shore, and finally the extensive wharves, with their roads, lines of rails, and stores, form the prominent feature of the new harbour of Trieste. These undeniable advantages, in place of the defective arrangements in the old harbour, are continually increasing in importance, and induce the English and Italian steamers, as well as the greater number of Lloyd's, to anchor here so as to obtain rapid and cheap loading and unloading, which equally benefit foreign and local trade.

In spite of the facilities afforded by the new harbour its trade is making but comparatively slow progress; during last year it amounted to 760,000 tons. This is only about thirty per cent. of the total traffic of Trieste harbour (import and export 2,400,000 tons) and only fifty per cent. of what the new portion is capable of undertaking, 1,517,000 tons.

This unfavourable result is partially due to the fact that vessels from force of habit still make use of the old harbour, but also arises from the temporary character of the arrangements of the harbour equipment. Technical, administrative, and maritime alterations might be made to produce the completion of the new harbour, which is now mainly dependent on the abolition of the free port. The harbour would then be in a condition enabling it to be utilized to its full capacity; but even this would not eventually suffice for the increase of the traffic which since the opening of the first dock in 1876 has, as the regular records show, been steadily on the increase. The import and export trade, has developed from 1,970,726 tons in 1876, to 2,409,610 tons in 1883, which gives an annual increase of 63,000 tons, and a total increase

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during the space of seven years of twenty-two per cent. In accordance with all precedent this increase ought to continue for a long while; there is, therefore, a well founded prospect of the care which the Government takes for the interests of their maritime emporium not ceasing with the completion of the new harbour, but of continuing, and finding expression in further action for increasing the Trieste traffic. This action ought to begin at a not very distant day, and take the direction of completing the warehouses as well as increasing the docks.

The communication is illustrated by three sheets of tracings and two lithographs, from which Plate 12 has been produced.

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(*Paper No. 2015.*)

"The Old Water-Supply of Seville."

By George Higgin, M. Inst. C.E.

The new Seville Waterworks, now in progress of construction by an English company, will destroy an ancient system of supply which has been in operation for more than seven hundred years.

Constructed in the year A.D. 1172 by the Moor Jucef Abu Jacub, whilst the City of Seville was still under the domination of the Saracens, it still exists in great part in the same original form in which it was first instituted—a standing monument to the conservative influences of the climate and people of the region where it is situated. Within a few short months all the most interesting features of this work of Moorish art will have disappeared.

The ancient Moors were always celebrated for their skill in dealing with water, and their application of it to irrigation, and many examples of their work in this respect still exist in Spain, in the primitive condition in which their constructors left them more than six hundred years ago; indeed it may safely be said that all the existing irrigation-works in Spain, now in active use, were originally designed and constructed by the enterprising Saracens.

The Author is not, however, aware of any existing system of town-distribution constructed by the Moors, so ancient and complete as that of Seville; and as this presents many points of interest to the engineer, a short account of it may be of use both in preserving an historical record of a work which is nowhere else recorded, and also as showing how, seven centuries ago, the then little understood principles of hydraulics were applied.

The old Seville water-supply may be divided into three parts.

First. The collection of the water.

Second. Its conduction to the city.

Third. Its distribution inside the city.

The first portion of the works, the collection of the water, is much older than the two latter portions, inasmuch as it is

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believed to have been done by the Romans in the early part of the Christian era, whilst Spain was still under their domination, and was used as a supply for the ancient city of Ontivar, a city which has long disappeared, and left only its name to tell of its former existence. The water is collected by a tunnel constructed in a rock of tertiary formation which forms the basin of a small river called the Guadaira. This river rises in the Sierra de Moron, near the town of Moron in the province of Seville, and after a short course falls into the Guadalquivir close to the city of Seville. The valley of the river for some distance above Seville is composed of a very porous argillaceous limestone, resting on a bed of impermeable clay, and at the junction of the two strata numerous springs occur, the principal of these being in the neighbourhood of the town of Alcalà, which is situated on the river Guadaira, at a distance of 13 kilometres from Seville. The head or starting-point of the tunnel referred to is in a depression near the edge of the river and at some 600 metres above the last houses of the town. In this place, and at 8½ metres below the ground, there is a circular chamber, excavated in the rock and communicating by a shaft with the surface, and from the bottom of this chamber numerous strong springs of clear water rise and flow away through a tunnel excavated in the rock. The height of the tunnel varies from about 4 feet to 5 feet 6 inches, it has a mean width of about 3 feet, but it is very irregular in shape and dimensions. The level of the water in this chamber is, in round numbers, about 22 metres above the streets of Seville.

From the first chamber the channel runs under the town of Alcalà, and almost in the centre of the town it is joined by a second tunnel, coming from another direction, and at a much higher level, the water of which is utilized to turn a most curious underground flour-mill, to which descent is made by means of a gallery leading down from the principal street of the town. The combined waters run on in a westerly direction under the town, and on emerging from it follow the course of the river for some little distance, till they arrive at the Arroyo de Zacatin. The tunnel makes a short detour at this point, keeping well under the bed of the stream, and afterwards continues on till it leaves the broken ground, and comes out into the open country at a distance of rather more than 3 kilometres from its origin. The depth of the tunnel below the surface of the ground varies according to the nature of the latter, but it is never less than 40 or 50 feet, and in some cases it is much more. Shafts communicate with the surface at every 50 or 60 metres, these being those probably used for the

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construction of the work. During the whole course of its progress through the tunnel, the stream receives additions to its volume from the numerous little springs encountered in its route, and it also loses somewhat from filtrations in those points where the tunnel approaches more nearly to the edge of the hills. At the upper part of the depression down which the Arroyo de Zacatin flows, a tunnel has been perforated into the hills, probably at the same time as the original work was made, and a considerable stream so obtained is utilized to actuate five flour-mills. At the point where this stream crossed above the tunnel, arrangements were made by means of shafts and connecting-tunnels by which the waters from the Zacatin tunnel could be turned into the main tunnel in case of shortness of supply. The total volume of water collected by the tunnel in the course of the 3 kilometres of its length, varies according to the nature of the seasons from 4,000 to 6,000 and even 8,000 cubic metres per day, say 880,000 to 1,320,000 and 1,760,000 gallons per day. The water is of excellent quality, a little hard, having about 16 degrees of hardness, but entirely free from organic matter, and containing only a very moderate quantity of salts in solution; it may be described as a first-class water for dietetic purposes. The Zacatin tunnel produces an average supply of about 500,000 gallons per day.

Considering the date of the construction of the tunnel, that the use of powder was not then known, and that for the distance of 3 kilometres the tunnel was excavated in the solid rock at a depth below the surface sometimes exceeding 150 feet, the industry and engineering talent displayed by these early masters of the profession may well be admired.

Conduction to the City.

During the time of the Romans the water after leaving the tunnel was probably led direct to the town of Ontivar, but after the destruction of this latter place and the occupation of the country by the Moors, the water was led by an open conduit down to a place called Torreblanca. Here it received an additional supply from another aqueduct and tunnel, the origin of which is lost, and from hence the united streams flowed on to a point now called the Cruz del Campo, 1,100 metres from Seville, giving power during their course to nine flour-mills.

From the Cruz del Campo the water was conducted by an aqueduct to the dividing house outside the old walls at the gate

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known as the Puerta de Carmona. Both the aqueduct and the watercourse are said to have been the work of the Moor Jucef Abu Jacub, A.D. 1172.

At a much later period, in order to avoid the pollution of the waters in the open course, the Town Council of Seville abandoned the nine mills which were their property, covered in the upper part of the course, and constructed another aqueduct for the purpose of carrying the water by a shorter channel over a depression in the ground, between Torreblanca and the Cruz del Campo. The level of the water at the Cruz del Campo before entering the old aqueduct is 11½ metres above the lowest part of the city, and at the dividing house outside the Carmona Gate it is nearly 9 metres.

Distribution of the Water within the City.

On the conquest of the City of Seville by the Spanish king, commonly known as Saint Ferdinand, he, in accordance with the custom of those times, took possession of the aqueduct and water, and the people were only allowed by royal favour, whatever water remained after the wants of his palace were satisfied, in the words of the old charters, of the surplus which was left after the "real casa y cocina" (royal house and kitchen) were satisfied. Immediately after the conquest, the king of course made large grants of lands and houses to his faithful followers, and at the same time he allotted to them portions of the water. Grants of water were also made to the numerous convents, which were then and afterwards established in the city. These grants are for the most part still valid, and the descendants of these old warriors, such as the Duke of Medina Coeli, and others, still claim a large share of the waters.

As time advanced, however, and the powers of the aristocracy decreased, whilst that of the townsmen increased, the administration of the water gradually fell into the hands of the town council. Public fountains were erected for the poorer classes, and portions of the water were sold or let off to the inhabitants. By degrees the quantity left for his majesty's palace grew smaller and smaller, and of the portion now claimed, his administrator considers himself lucky if he receives one-fourth part, whilst many of the old grantees are compelled, against their will, to suffer a similar reduction.

The Author will now describe the system, by which the waters were divided and conducted to the house. Before doing so, however,

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it will be advisable to describe the unit of measure used in the regulations for supply. This is the "paja," the Spanish word for straw, and was doubtless originally meant to be as much water as would flow through a pipe having an internal diameter similar to that of a straw. Even supposing the diameter of a straw to be unvarying, it is evident that the amount of water flowing through it would depend directly on the head, and it can scarcely be conceived that the old Moors were not cognisant of this; but neither tradition nor written evidence has handed down any definition as to the head that was assumed, as that necessary, and though doubtless popular custom assigned some more or less regular head, yet at the present day it is impossible to find any reliable data on which to base it.

As regards the dimensions of the "paja," this was fixed at a comparatively early date, and amongst the archives of the municipality of Seville there is preserved an ancient document on vellum, in which the dimensions of the orifices necessary for the various discharges are shown graphically. On Fig. 1, the Author has reproduced the sizes from $\frac{1}{4}$ paja up to 10 pajas.

The heading of the old document referred to says:—

"The ancient and modern measures used in the distribution of the waters of the Carmona aqueduct of this city of Seville, in the times of our lords the Catholic kings, and of their predecessors, such as our lord the king Don Juan of famous memory.

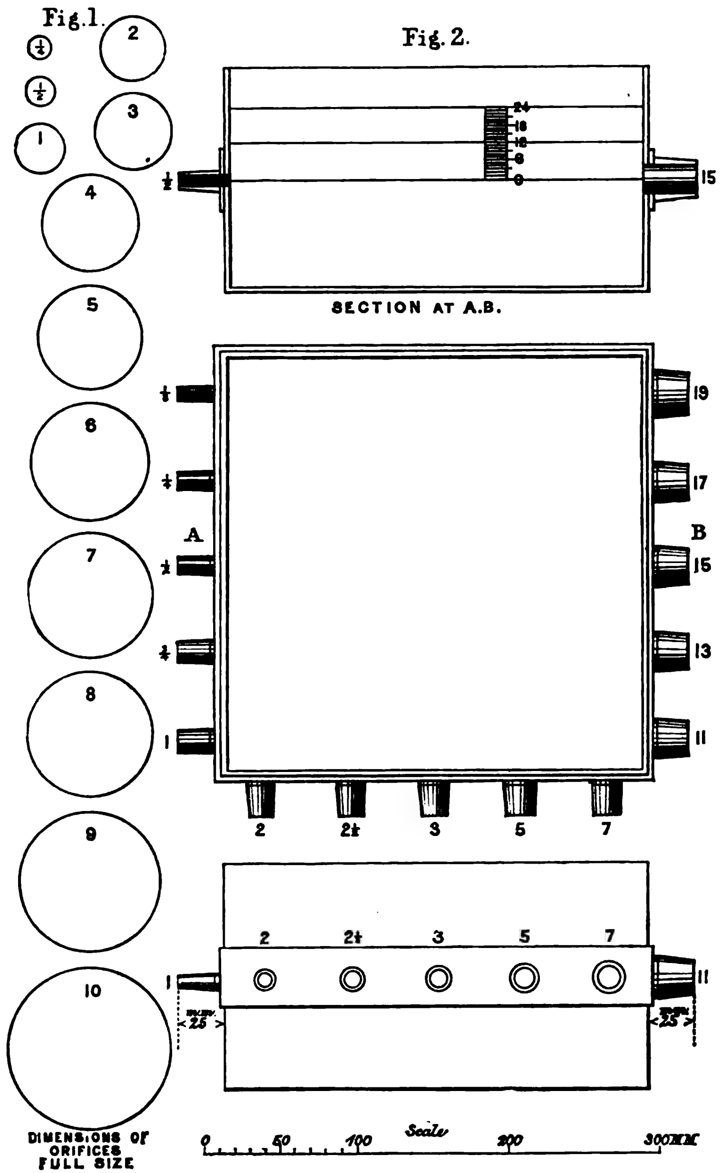
"By order of my lord Don Juan Francisco Navarette, of the council of H.M. and his judge of the royal tribunal of this city of Seville, and inspector of his royal palaces, and of the waters of the Carmona aqueduct.

"Made in the year, 1657.

SEBASTIAN DE RUESTA."

According to this document the diameter of the orifice for "one paja" is as nearly as possible 6 millimetres, or say $\frac{1}{50}$th of a Spanish foot, and the discharge of the various orifices is shown to vary as the square of the diameter.

There exists also in the municipal archives a brass box, which is used, or was used, for measuring the water supplied to any house, in case of complaint. This box, shown by Fig. 2, is 10·82 inches square and 5·70 inches deep, and contains on three of its sides openings marked respectively from $\frac{1}{8}$ "paja" to 19 "pajas;" on the third side there is a scale, which, starting from the centre of the orifices, marks 2 Spanish inches, each inch being divided into 12



Old Water-Supply of Seville.

Details of Metal Box for Measurement of Water, preserved in the Archives of the Town Council.

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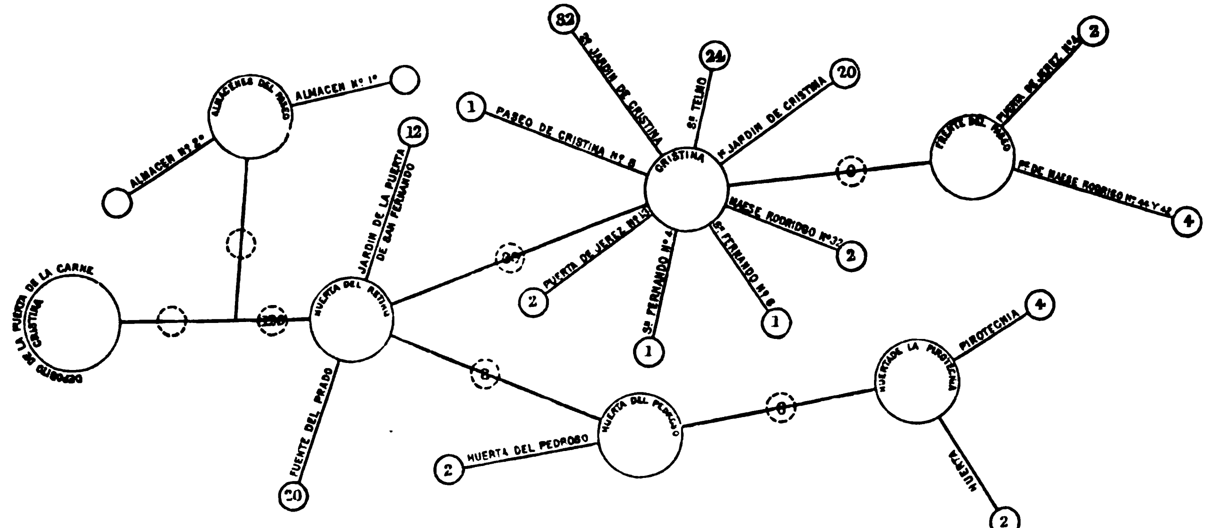
Fig. 3.



OLD WATER-SUPPLY OF SEVILLE.

RAMO DE CRISTINA.								
Numeros.	——	Cuartas.	Numeros.	——	Cuartas.	Numeros.	——	Cuartas.
..	Almacen	} ..	..	Jardin de la Puerta de San Fernando . . . . . }	12	13	Puerta de Jerez	2
..	Id.					4	Id.	2
..	Fuente del Prado	20	..	Id. de Cristina primo	32	..	Pirotecnia	4
4	San Fernando	1	..	Id. Id. segundo . .	20	8	Paseo de Cristina	1
6	Id.	1				..	Palacio de San Telmo . . .	21
..	Huerta del Pedroso	2	32	Maese Rodrigo	4			
..	Id. de la Pirotecnia . .	2	42 y 44	Id.	2		Suma	130

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lines. It would appear from this box that the proper head should be 1 inch, as it is probable that the gauge was meant to ascertain whether any given pipe was discharging more or less than a "paja," and how much.

A series of very careful measurements made by the Author with this gauge, to determine the value of the "paja," gave with 1 inch head, the following results:—

Dimension of Orifice.	Discharge in 24 hours in Litres.
$\frac{1}{8}$ paja	270·84
$\frac{1}{4}$ "	434·17
$\frac{1}{2}$ "	604·19
$\frac{3}{4}$ "	1152·00
1 "	1661·53

According to these experiments, the value of 1 "paja" would be equal to about 365$\frac{1}{2}$ gallons, and this is probably more than most of the old grantees receive, although there is a general idea prevalent in Seville, that the "paja" ought to be nearly double the amount mentioned above. The relation between the various quantities is as close as could be expected under the circumstances, as the constructors do not appear to have understood the influence of the adjutages, and these are all the same length, that for $\frac{1}{8}$ "paja" being the same as that for 19 "pajas."

The Author will now proceed to describe the system of distribution:—

The water on arriving at the city is delivered by the aqueduct into a covered reservoir, which is under the charge of an officer of the municipality, and to which no one has access without permission. The plan and section of this reservoir are shown on Plate 13, Figs. 4 and 5. The wall bounding the reservoir on one side, which is a half octagon, contains eight orifices, corresponding to eight principal mains serving the city. The first of these orifices, which is near the level of the floor, corresponds to the main supplying the royal palaces, and the opening communicates direct with an earthenware pipe. The remaining seven orifices communicate with a second chamber, from the bottom of which the pipes for the supply of each principal main lead off perpendicularly. These orifices are all provided with a bronze frame and diaphragm, pierced with holes of various dimensions. The orifice belonging to the royal palaces is 14 inches lower than the remaining seven, so that His Majesty has a decided advantage over his subjects.

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The translation of the original document, preserved in the archives describing these various orifices, is as follows:—

No. 1. Pipe belonging to the royal palaces, which takes all the water of which it is capable. Its dimensions on the upper part is 14 inches, and on the lower part 9½ inches; it does not possess its proper frame.

No. 2. Known as "Barca Rota," in which is placed a bronze frame, having one opening, whose dimensions are equivalent to 23 "pajas" of water.

No. 3. Known as "Colegial del Salvador," in which is found another frame of the same metal, with five openings. The first of 11 pajas; the second of 13; the third of 13; the fourth of 14; and the fifth also of 14, making together 65 "pajas" of water.

No. 4. Known as the City pipe, in which the water travels to the public fountains, the square of San Francisco, Calle Laguna, the Triana Gate, and the Square of La Magdalena, where is found another frame of the same metal as the former ones, having three orifices. The first of 24 "pajas"; the second of 30; and the third also of 30, making up 84 "pajas" of water.

No. 5. Known as "San Pablo," is also of bronze. It consists of two orifices; the first of 18, and the second of 21 "pajas," making together 39 "pajas" of water.

No. 6. Known as "Medina Sidonia," of the same metal as the others, in which are six circular orifices, as are all of this principal main. They consist: the first of 36; the second of 16; the third of 13; the fourth of 13; the fifth of 11; and the sixth of 18; which added together make 107 "pajas" of water.

No. 7. Known as "Baños de San Juan de la Palma" consists of two orifices. The first of 22, and the second of 17, together 39 "pajas" of water.

No. 8. Known as that of the "Duke of Medina Coeli," consists of one sole orifice of 18 "pajas" of water.

It will be noted that whilst many of the openings have a number of orifices of a specified size, the entire body of water delivered by them is carried off by one down pipe in the second chamber. The reason of this is to be sought in the historical antecedents of the system. As fresh grants were made by the king, or at a later period by the municipality, a new hole was bored in the frame, the size of which corresponded to the dimensions shown on the old documents, for the number of pajas granted. The main pipe was always supposed to be, and indeed was, large enough to convey all the water required; the measurement into

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the main pipe was made at this chamber, and the measurement to the proprietors was made, as will be hereafter described, at the various distributing-boxes in the city.

The head of water over the orifices is that due to the difference of head between the two chambers, and is generally an inch or two. No means were provided for throttling the down pipe, but as the number of pajas admitted at the distributing chamber is, of course, exactly that distributed to the proprietors, the head of water is supposed to be balanced so as only to give the requisite discharge. Were the pipes sound and the distribution accurate, this would be so in practice. There is, however, a good deal of inequality in the distribution, and there is a large loss from leakage; but from long practice the distributors manage to make a pretty fair distribution to the various mains in chamber. The leakage is compensated for by a general discount on all the houses; and if, as often takes place, one proprietor gets more than his share, it is taken off some other proprietor, who has not had the astuteness to satisfy the official distributor. The principle of measurement is sound; it is virtually a discharge through a thin plate under a known head, and is the best and most efficient means of measuring. The openings in this main chamber have no adjutages; from which it is evident that the original constructors of this work knew more of the true principles of hydraulics than the constructors of the gauge-box.

The pipes for the conduction of the water through the streets were originally of earthenware surrounded by brickwork; many of these pipes, put down hundreds of years ago, are still doing service, but in some cases they have been superseded by cast iron. The smaller services are all of lead.

As there is occasionally a head of 25 or 30 feet on the pipes, it is evident that the leakage from the old class of pipes was, and is, considerable. It is wonderful, however, to see how well they have stood the pressure. As a matter of fact, however, out of the 4,000 metres of water per day brought into the city by the old aqueduct, not much more than one-half ever reaches its final destination.

Figs. 7 and 8, Plate 13, will explain how the distribution is made to the houses. Fig. 8 is an exact copy of one of the old plans kept in the municipality, and shows the mode of distribution in one of the small districts. The circles shown on the plan represent the dividing-boxes, the section and plan of which are shown on Fig. 7. The distribution is effected by means of a small metal box, placed in the outside wall of one of the houses, at such

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a height that the level to which the water will rise at this portion of the city shall about one-half fill the box. A lead pipe about 4 inches in diameter inserted in the bottom of the box communicates with the main. The side of the box is perforated with as many holes as there are participants of the water flowing from this box, and the dimensions of the orifices correspond to the amount of pajas each one should receive. The water flowing from the orifices is caught in a small hollow made of cement, from which a lead pipe leads it down into the street and thence to the house of the owner. Many of these boxes serve for the division of the water from other boxes. In Fig. 8, Plate 13, it will be seen how this is done. The box G, at the corner of the Calle del Carpio, receives its water from a pipe coming down that street, and supplies five private houses and five secondary boxes, three of which are shown on this plan, lettered G′, G″, G‴, and the remaining two are in another district. This box therefore contains ten orifices of varying dimensions.

The large book preserved in the municipality contains plans of every district supplied similar to the one copied here, and also a series of plans or diagrams, of one of which Fig. 3 is a copy, showing the boxes situated on each main, and the houses supplied from each box. Thus the Christina box supplies eight houses, the number and street of each being written on the diagram. At the side of each diagram is a statement showing the street and the number of each house, and the amount of water it is to receive counted in fourth parts of "pajas."

The old boxes were mostly of iron or bronze, the metal being from $\frac{1}{8}$ to $\frac{1}{4}$ inch thick; they are of various shapes, some being oval and some square; as a rule they are about a foot square, and 9 inches deep. They are at varying heights above the street, according to the level of the latter.

It is evident that, theoretically, this system of measuring the water was good, and if a uniform head could be kept, there would be nothing to object to. Practically there were many drawbacks. There was no effectual way of controlling the head; the boxes were fixed in accordance with the height to which it was ascertained by actual experiment the water would rise; but once fixed, many causes combined to render the pressure a constantly varying one. The men in charge of the various districts manipulated the boxes in accordance with their hereditary practical instincts, and a kind of rough-and-ready justice was administered. Thus, in one box where there was too great a flow of water, either from the box having been fixed originally too low or a

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greater pressure having been given by the laying of new and larger mains, the Author saw that a half brick had been placed on the inlet-pipe, and by this means the head was kept down to about 4 inches. The keys of all the boxes are kept by the head water-bailiff; and it is easy to understand what power this gave to a shrewd practical man who understood, in his own way, how to increase or diminish the supply to each house. His position thus became a lucrative one. To obtain one's full supply it was necessary to be on good terms with him, whilst those who had not thus provided for themselves found their supply daily growing smaller and smaller. At the same time a kind of practical balance was maintained in each district.

It will be easily understood that, after its numerous journeys, and the large amount of friction to which it was subjected, the water had not much power remaining when it arrived at the houses. In few houses, even in streets at the lowest level, did it rise many feet above the level of the floors; almost all, if not all, the houses which have water, collect it in a marble cistern, from whence it is pumped up by hand-power to the upper floors.

The new waterworks, now far advanced towards completion, will sweep away all the old system of distribution. They take the water at the conclusion of the tunnel and pump it up by steam-power to reservoirs constructed near the town of Alcalà, from whence it will be conducted by a 21-inch main to the city and distributed under a mean pressure of 25 metres head, so as to rise to the top floors of the highest houses.

Before all the data for doing so vanish, the Author thought that a description of these ancient works would probably interest the profession, as giving an account of perhaps one of the oldest systems of house-distribution known in connection with the water-supply of towns.

The communication is illustrated by four sheets of small scale drawings, from which Plate 13 and the woodcuts, Figs. 1, 2, and 3, have been prepared.

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(*Paper No. 1964.*)

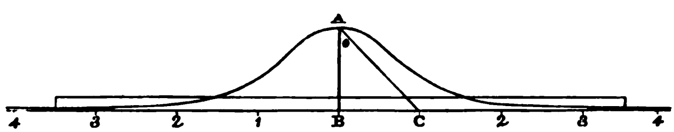
"A Dioptric System of Uniform Distribution of Light."

By ALEXANDER PELHAM TROTTER, B.A., Assoc. M. Inst. C.E.

IT may be said of ordinary electric-arc lights, as used for out-door lighting, that they have three distinct and prominent faults. First, there is too much light in the immediate neighbourhood of the lamp. Secondly, there is not enough light at a distance; and thirdly, a considerable quantity of otherwise useful light is wastefully sent towards the horizon.

The illumination of a plane area by rays emanating from a point is inversely as the square of the distance from the origin, and directly as the cosine of the angle of incidence. This law of distribution may be represented graphically by a curve, whose ordinate at any point on the base is a measure of the illumination

FIG. 1.



at that point. Taking the length A B, (Fig. 1) (representing the degree of illumination at that point on the plane nearest to the source of light), as unity, the degree of illumination at any point, C, is $\frac{\cos\theta}{\text{A C}^2} = \cos^3\theta$; the equation to the curve is $y^2 = \left(\frac{1}{1+x^2}\right)^3$, taking B as origin, and the solid contents of the figure of revolution of this curve about A B is 2π. (Appendix *a.*)

In the problem of the uniform illumination of a circular plane area from a source of light situated above its centre, there has to be considered, first, the height of the lamp above the ground, and secondly, the diameter of the circle. Practical considerations show that the diameter of the circle should not be less than twice the height of the lamp above the ground; and undue length of shadows points to a maximum diameter of ten times this height.

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If seven times be taken as a convenient ratio of diameter to height, then the degree of illumination at any point will be represented by the height of a cylinder whose diameter is seven times its length, and whose volume is equal to that of the said solid of revolution. This is 0·163. That is, at any point on the area, the illumination will be 0·163 of the maximum on the ordinary distribution.

The Author was led to consider this problem, by the observation that not only is the light of arc lamps approximately proportional to the square of the current, but also that by reason of the first cost of an installation, and what is afterwards a most serious matter, the cost of attendance, carbons, &c., for each lamp, it is a matter of the greatest importance to keep the number of centres of light to a minimum. In fact, the cost of the power is so small compared with the other expenses, that if the same illumination can be produced by one lamp instead of two lamps, the cost is practically one half.

Various considerations tend to limit the height of the lamps, in this country at all events, to about 30 feet. It is, therefore, a necessity that some means should be adopted for increasing the illumination of the parts remote from the lamp. It will be noticed in the curve of the law of distribution (Fig. 1), that, under ordinary circumstances, the illumination falls off so rapidly that at a distance of three-quarters of its height from the foot of the post it has decreased by one half; at an incidence of 45° on the ground, there is 0·353, and at a distance of twice the height of the lamp, there is but 0·0316 of the maximum. It is true that this maximum is very rarely attained, there being few existing systems in which there is not a shadow below the lamp. But this does not affect the argument.

In considering the problem, it may be assumed that the light is emitted from one central source, and that the area to be illuminated is circular. Suppose this area to be divided into annuli of equal area, the radii being as $\sqrt{1} : \sqrt{2} : \sqrt{3}$, &c., the same quantity of light has to be directed to each annulus. Hence the rays, emanating at equal angles with each other, must be so refracted, that the tangents of their new inclinations to the vertical are as $\sqrt{1} : \sqrt{2} : \sqrt{3}$, &c. (Fig. 2.)

The only previous attempts at the solution of the problem that the Author has met with are in the patent of Smethurst and Paul, dated 1802, and in Fresnel's works, where a reflector for the uniform illumination of a clock face is described. Smethurst and Paul describe a reflector "that shall be so formed as to reflect

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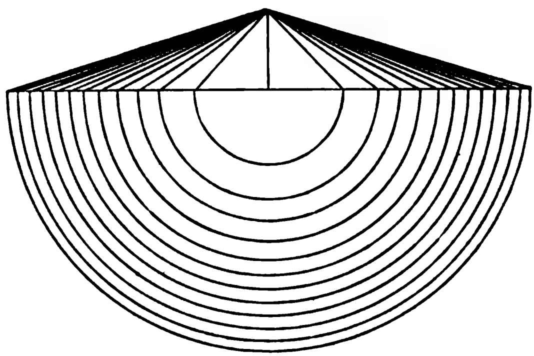
those rays issuing from the frame of the lamp, which, without their interposition, would fall in a direction in which they would be useless, according to the purpose for which the lamp is applied, in such a manner as to diffuse and distribute them over the whole surface or extent of space to be illumined, so that the whole of the light falling on every portion of such surface or extent of space,

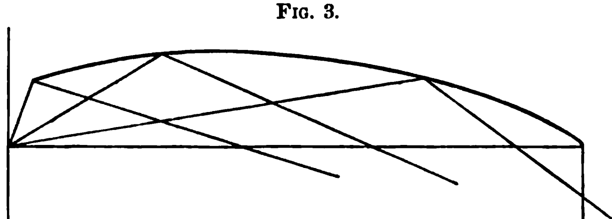
FIG. 2.



both from the direct rays of the lamp and after reflection from the reflector, may be as nearly equal and uniform as is practicable."

In the description of their method, however, they do not deal with the direct rays, so that they merely attempt to superimpose a uniform distribution on an already unequally illuminated area; and moreover they fall into the error of directing the rays at

FIG. 3.



angles whose tangents are as 1 : 2 : 3, &c., instead of as $\sqrt{1} : \sqrt{2} : \sqrt{3}$, &c. This error being corrected, a curve (Fig. 3) can be constructed, with reference to a focal origin, and a reflector generated by the revolution of this curve about a vertical axis passing through this focus. The combination of this, with a hemispherical reflector below the light, is the simplest possible solution of the problem; but it is not worth while putting it into practice on

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account of the serious loss from absorption in the best reflecting material.

It may be well to state that it is not possible to illuminate satisfactorily the more distant parts of the area by merely reflecting thither the otherwise useless rays.

In most electric lamps so large a proportion of the light is thrown downwards, by the crater of the positive carbon, that an optically designed reflector is hardly worth the cost.

Dealing with the problem by refraction, considering one vertical plane; and dealing only with the rays passing in directions below the horizon; the simplest method is to direct the rays making large angles with the vertical toward the more distant parts of the area to be illuminated; and those making small angles with the same towards the more central parts of the area.

Neglecting the rays which make less than 15° with the vertical, as these are generally obstructed by the mechanical arrangements of the lamp, if the source of light be $\frac{1}{7}$ of the diameter, above the centre of the area, the inclination of the limiting ray will be 74° 12′; the horizontal ray has to be deviated, therefore, through 15° 48′, and the others must be deviated, in the manner explained above, towards the proper point on the area.

The required deviation of the rays can be most readily produced by making the glass lantern in the shape of an inverted cone: for by the refraction at the first surface the upper rays are deflected downwards, and the lower rays upwards, within the substance of the glass. Taking a right-angled cone, the horizontal ray has an incidence of 45°, and the angle of the prism necessary to produce a deviation of 15° 48′ with this incidence is 24° 30′ ($\mu = 1 \cdot 51$).

Taking a number of rays, say twenty, emanating at equal angles with each other, incident on the inner surface of the cone at known angles, the refracting angle for each ray is determined, so that, on leaving the glass, the tangents of their inclinations to the vertical are in the relation of the square roots of the natural numbers. A polygonal figure is thus found, and from this the curve to which it approximates—as the number of pencils is made infinitely large—is drawn (Fig. 4). To put this in a practical form, to avoid excessive thickness of glass, prismatic zones would be formed, as in the polyzonal lenses of Brewster, &c., each zone having the curvature of the part of the virtual curve to which it corresponds.

There are, however, two important disadvantages attending this method. First, the light received at any point on the illuminated area is emitted from a corresponding point on the glass, and is

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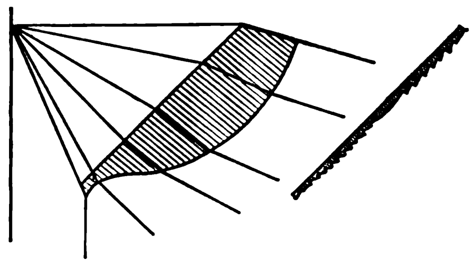
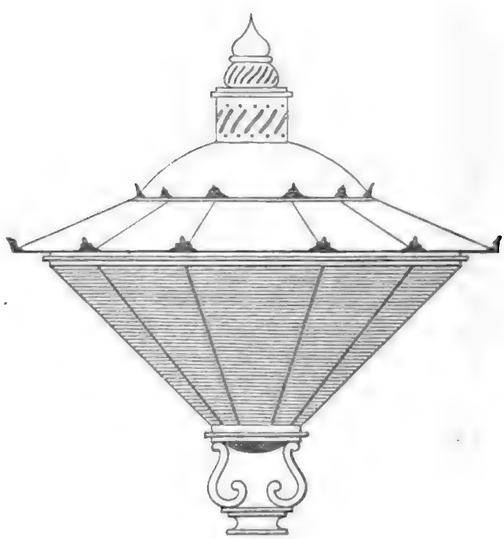
therefore, as dazzling as a naked light; secondly, if the light be not emitted uniformly from the source, as in the case of most electric arc lights, there will be a corresponding inequality of distribution.

FIG. 4.



The system adopted has been to form a number of prismatic zones, of such curvature that light passing through each is distributed in the required proportion over as much of the area as is possible, without so near an approach to the critical angle as to incur risk of chromatisation or of total internal reflection.

FIG. 5.



These prisms are formed at $\frac{1}{4}$ inch pitch on the surface of a sheet of glass, by a peculiar process of moulding or pressing. Ten panes of this glass go to form an inverted cone having

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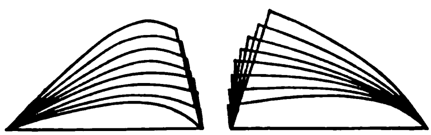
a base of 2 feet 6 inches, Fig. 5. A smaller pattern for use with incandescence-lights, is a cone 12 inches in diameter, made in one piece.

The calculations for these prisms were made graphically thirty times full size. As an example:—The figure of the uppermost prism is found as follows. The width being small compared with the distance from the focus, the rays are assumed to be parallel. The incidence in this case is 45° (Fig. 6). The glass used has a refractive index of 1·51. The internal deviation will be 17°. The series tan θ calculated to the nearest 15′ for a series

FIG. 6.



of twenty-five angles, the limit being 17° 45′, is:—0°, 35° 15′, 45°, 50° 45′, 57° 45′, &c. It is required to deflect one of each of the twenty-five rays to one of these angles respectively. The first ray, θ, is beyond the power of the glass; the second, 35° 15′, is too near the critical angle; the next, 45°, requires an angle of 64° 45′ as the angle of the prism; the next, 54° 45′, requires an angle of 57°, and so on for each of the series. These angles are set out, and the curve, to which the resulting polygon is approximate, is drawn (Appendix C). It should be observed that in this construction each angle is measured with the base, so an error does not accumulate.

Fig. 6 shows a series of sixteen of these curves, called distribution curves, corresponding to rays making angles of 89°, 80°, 75°, 70°, &c., with the vertical. Each curve is terminated by a surface parallel to the path of the adjacent ray within the glass. It is only in the extreme cases that the refractive power of the glass is not sufficient, with the given angle of the incidence, to produce the required deviation of the ray, and where one prism fails to send the light to certain portions of the area to be illuminated, others supply the deficiency by sending a proportionally larger quantity of light to these parts. This is done also by a graphical method which it is not necessary to explain, as it is not connected with the optical theory of the problem.

Each prismatic zone then sends light to a considerable portion of the area; and conversely, from any position on the area, light is received in uniform quantity from a considerable number of the

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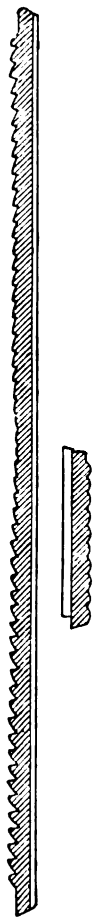
prisms, but only from one point on each. The light would therefore proceed from a row of images in one vertical plane. If the original emission is not uniform at different angles with the horizon, these images will not be of uniform brightness, but the resulting illumination of the area will be unaffected.

Fig. 7.



Vertical section ¼ full size.

Horizontal section.

Such an arrangement would afford but little improvement on the one first described, as far as its dazzling appearance is concerned.

To meet this, a series of vertical flutings is produced on the inner surface of the cone, as in ships' lanterns and on a larger scale in some lighthouses; but to obtain uniform lateral dispersion, the section of these flutes is a curve, the construction of which will be presently explained. The same result might be obtained by combining the two series of curves to form lenses, whose figure would be generated by a distribution curve sweeping through a dispersion curve. This was the Author's first design, when it was intended that the inner surface of the cone should be smooth, but the former method was adopted on account of the simplicity of the mould.

The production of a pane of glass of the required size, presented such difficulties, on account of its shape and dimensions, irrespective of the optical design, that the work was declined by some half-dozen of the leading manufacturers. The glass is now produced by Messrs. Moore & Co. of South Shields. Each pane for the 2 feet 6 inches lantern is 14 inches long by 8 inches at the top end, tapering to 2 inches at the bottom. A complete section of it is shown in Fig. 7. Ten of these go to form the cone. The curves are reduced by a pentagraph to the required size, and are drawn on sheet brass from which templates are cut. To these templates tools are ground, and thus the requisite grooves are cut in the moulds. A more accurate method, which will be adopted in future, is to reduce the curves to four times full size, by photography, and then to cut the tools by means of a pentagraph drilling machine.

Diffusion.—Opal and ground glass is commonly used to lower the light in intensity in order to avoid dazzling. As is well known, this "softening" of the light is attended by a serious

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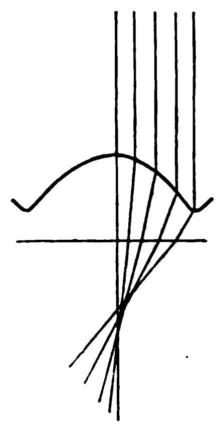
loss by absorption, varying from 40 to 60 per cent. But diffusion of light need not necessarily be attended by any loss by absorption: nor need the intensity or quality of the light be affected; though this may sometimes be an advantage when the colour is crude, owing to the use of cheap carbons or high electromotive force.

By forming a series of small lenses (Fig. 8) of a certain figure, or by two series of flutings, one on each side of the glass at right angles, the light as seen from any point is spread out into a sheet of images of the actual light. On an 18-inch globe, some 6,000 points of light would be seen by using lenses or flutings of $\frac{1}{4}$-inch pitch. Each of these points would be $\frac{1}{6000}$ of the power, but of the same intensity and quality as the light itself. The loss by absorption of such a shade is only 10 to 15 per cent., as against 40 to 60 per cent. in ground or opal glass. The greater part of this is due to mere reflection at the surfaces of the glass.

Fig. 8.



The difficulties of manufacture of the large diffusing globe have not yet been overcome; but small shades are in use, in which a powerful incandescence-lamp appears as a uniform sheet of from 200 to 300 bright points. The utility of the special curve may readily be seen by comparing one of these shades with one attempting to produce the same effect by haphazard ornamental cutting, in which case a large amount of light is lost by repeated internal reflection.

The uniformly diffusing curve is obtained by drawing say ten lines, representing ten parallel rays. One of these passes directly through the glass; the next is to be deflected through say 5°; the requisite refracting angle is found and set out; the next ray is to be deflected through twice this amount; and the next through 15°, until the critical angle is approached. The curve to which the resulting polygon is an approximation is then the curve required. The analytical investigation of this curve will be found in Appendix (*b*).

For the purpose of diffusion only, a compound curve operating by total reflection and refraction has been designed (Fig. 9). This gives uniform diffusion through about 150°. This must be used on the exterior surface of the glass, and cannot well be combined with the distributing system.

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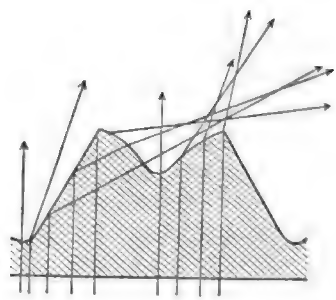
The use of lateral diffusion in the distributing lanterns is not limited to the mere agreeable softening of the light, but by suitable disposition of the flutings the light can be so concentrated as to

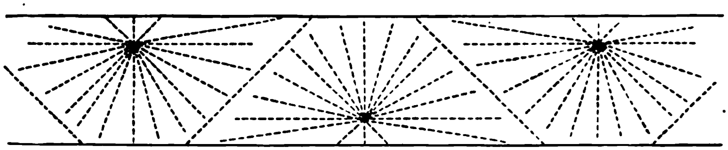
Fig. 9.



illuminate a square or triangular-shaped area; a modification of the latter being specially adapted for street lighting (Fig. 10).

The whole of the calculations for the curves were carried out graphically by geometrical construction on a large scale. The

Fig. 10.



angles were found by a refraction goniometer designed and made for the work, and without which the labour would have been very considerable.

The analytical investigation of the various curves alluded to in the Paper have been worked out by the assistance of Messrs. J. W. Welsford and C. A. E. Pollock, and will be found in an Appendix.

The Paper is accompanied by several diagrams, from which the woodcuts in the text have been prepared.

[Appendix.

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APPENDIX.

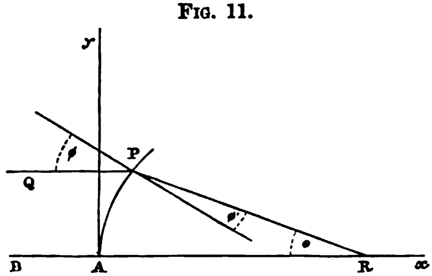
ANALYTICAL EXPRESSIONS.

(*a.*) $\int_0^\infty 2\,\pi\,x\,y\,d\,x = 2\,\pi \int_0^{\frac{\pi}{2}} \tan\theta \cos^3\theta \frac{d\,\theta}{\cos^2\theta} = 2\,\pi \int_0^{\frac{\pi}{2}} \sin\theta\,d\,\theta = 2\,\pi.$

(*b.*) The shape of the curve formed by a horizontal section of the fluting is determined as follows:—

If B A R, Fig. 11, be the ray which passes through without refraction, Q P R a ray refracted at P. Let the angle P R A = θ. Then θ is to be proportional to the perpendicular distance of P from B R.

FIG. 11.



Taking A as the origin, A R as rectangular axis of x, and a line perpendicular to it as axis of y, then, if $x\,y$ be co-ordinate of P,

$$\theta = c\,y, \text{ where } c \text{ is a constant}$$

$$\sin\phi = \mu \sin\phi'$$
$$\phi = \phi' + \theta$$
$$\frac{d\,y}{d\,x} = \cot\phi$$

ϕ and ϕ' being angles which the incident and refracted rays make with the normal.

Then
$$\sin\phi = \mu \sin(\phi - \theta)$$
$$\sin\phi\,(\mu\cos\theta - 1) = \mu\cos\phi\sin\theta$$
$$\tan\theta = \frac{\mu\sin\theta}{\mu\cos\theta - 1},$$

or
$$\frac{d\,y}{d\,x} = \frac{\mu\sin c\,y}{\mu\cos c\,y - 1}.$$

Integrating
$$x = \frac{1}{c}\log\frac{\mu - 1}{\mu\cos c\,y - 1}.$$

(*c.*) The relations which hold for the co-ordinates of any point P on the curve are as follow:—

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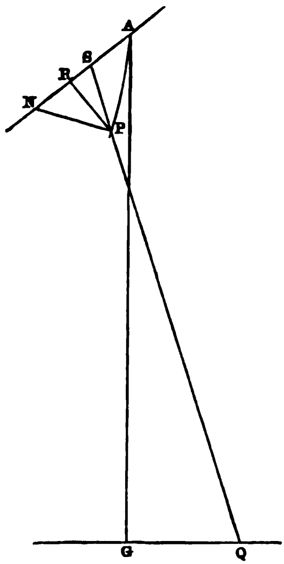
A C, Fig. 12, is the extreme ray which is refracted vertically, A B is drawn perpendicular to the path of the rays in the glass, P N the normal to the curve at A, P R a ray in the glass, and P Q the same ray after refraction.

FIG. 12.



Then since C is practically at the centre of the illuminated area—

$$A R = a^2 C Q^2 \quad . \quad . \quad . \quad . \quad \text{(i.)}$$

where a is some constant—

$$C Q = b \cot P Q C \quad . \quad . \quad . \quad \text{(ii.)}$$

where $b = A C$.

$$P Q C = \pi - \alpha - P S R$$

where α is the angle between A B and the horizontal.

$$= \frac{\pi}{2} - \alpha + S P R$$

$$= \frac{\pi}{2} - \alpha + S P N - R P N$$

$$\therefore C Q = b \tan (\alpha - S P N + R P N)$$

If A be taken as the origin and A B as the rectangular axis of x, then R P N is the angle between the tangent at P and the axis of x.

$$\sqrt{x} = a\, b \cot P Q C$$
$$= a\, b \tan (\alpha - S P N + \psi),$$

where $\sin S P N = \mu \sin \psi$

$$\therefore \sqrt{x} = a\, b \tan (\alpha - \sin^{-1} \mu \sin \psi + \psi) \quad . \quad \text{(i.)}$$

and, $$\frac{d y}{d x} = \tan \psi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad \text{(ii.)}$$

Between these a differential equation to the curve may be found. It may be observed that a is the only constant that will practically vary in the series of curves.

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(*Paper No. 2003.*)

"The System of Coaling at the Works of the late London Gaslight Company, Nine Elms."

By Robert Morton, M. Inst. C.E.

Until the year 1878 the coaling at these works was done by the old-fashioned mode of transhipment from steamers below London Bridge, and conveyance thence in open barges carrying from 50 to 100 tons each, it being then deemed impracticable to navigate sea-going craft through the bridges. This system is open to many objections, such as, breakage of the coal in transhipment, loss from theft and the occasional sinking of a barge, and the wet condition in which the coal often arrives at its destination through stress of weather and unsound craft—a very serious matter in gas-making—not to speak of waste of time, extra cost in freight and labour, and the extreme difficulty sometimes experienced in getting such craft up the river when it is to any extent blocked with ice. Notwithstanding these and other drawbacks, and a six-years' practical demonstration of the better and cheaper system now in use at Nine Elms, this remains, with that one exception, the universal practice above bridge.

The idea of bringing coal direct from the port of shipment to their works at Nine Elms was not new to the Directors of the London Gas-Company; but it was only in the year 1876 that the feasibility of constructing vessels for the purpose, of from 800 to 1,000 tons burthen, and the attendant advantages of the plan, were prominently brought before them by a gentleman interested in the shipping part of the question.

The Company had not power to build and own ships. They communicated with several shipping and ship-building firms on the subject; some offered to provide ships at the company's risk, others refused to have anything to do with it, pronouncing the scheme impracticable. The Directors were not of that opinion, and they publicly offered to freight suitable vessels for a term of years, guaranteeing a proper berth at Nine Elms with a depth of 12 feet at high water of neap tides. This offer drew forth several responses, and ultimately a tender was accepted and a contract entered into, with sufficient sureties to protect the Company

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from loss, on the outlay they would necessarily incur in providing a berth and discharging machinery, should the attempt fail.

Instructions were given to the engineer to prepare plans and estimates. The necessary works were carried out at a cost of about £20,000.

Two ships were provided by the contractors, and on the 9th of July, 1878, the "Vauxhall" arrived at Nine Elms, thirty-six hours from Jarrow, and put out 1,022 tons of coal. The passage of the steamer above London Bridge was watched with great interest, especially by the Thames watermen, who, having declared that such ships could never be navigated through the bridges, did all in their power to prove the soundness of the assertion. The dimensions of the "Vauxhall" and of her sister ship the "Westminster" are: length, 220 feet; breadth, 32 feet; depth (of hold), 13·85 feet; mean draught (with 1,000 tons freight) 12 feet.

In the following year a third ship, the "Lambeth," was built, of similar length and beam, but with a depth of 14·5 feet. She has put out 1,147 tons of coal on a mean draught of 13 feet 5 inches. Each ship is fitted with engines of 100 HP. and has steam steering-gear; the funnels and masts are made to lower, and although the light draught necessarily entails a flat bottom, yet they are good sea-going boats. The quickest passage made as yet has been thirty-four hours from the Tyne to Nine Elms.

The nature of the foreshore and frontage at Nine Elms favoured the plan of a berth at right angles to the river, as shown by the annexed sketch; and although this would entail a little delay in berthing the ships, the advantage of getting them into a much safer position, 100 yards nearer the coal stores, and alongside a wharf constructed on the company's own ground, determined the engineer to carry it out. On the wharf, and parallel to the ship, an elevated platform has been constructed on a level with the original tramways in the factory; this consists of a series of columns and girders decked over, and carries four lines of rails, which converge to a weigh-bridge at the junction of the platform with a double-line viaduct leading to the stores and retort-houses. The coal is lifted from the ships by means of three hydraulic jib-cranes which rise from the wharf level; these are constructed of light steel plates and angles, in the shape of bent box-girders, rectangular in section, the jib portion tapering towards the outer end, the chain passing down inside; they are attached to the front of the platform by races in

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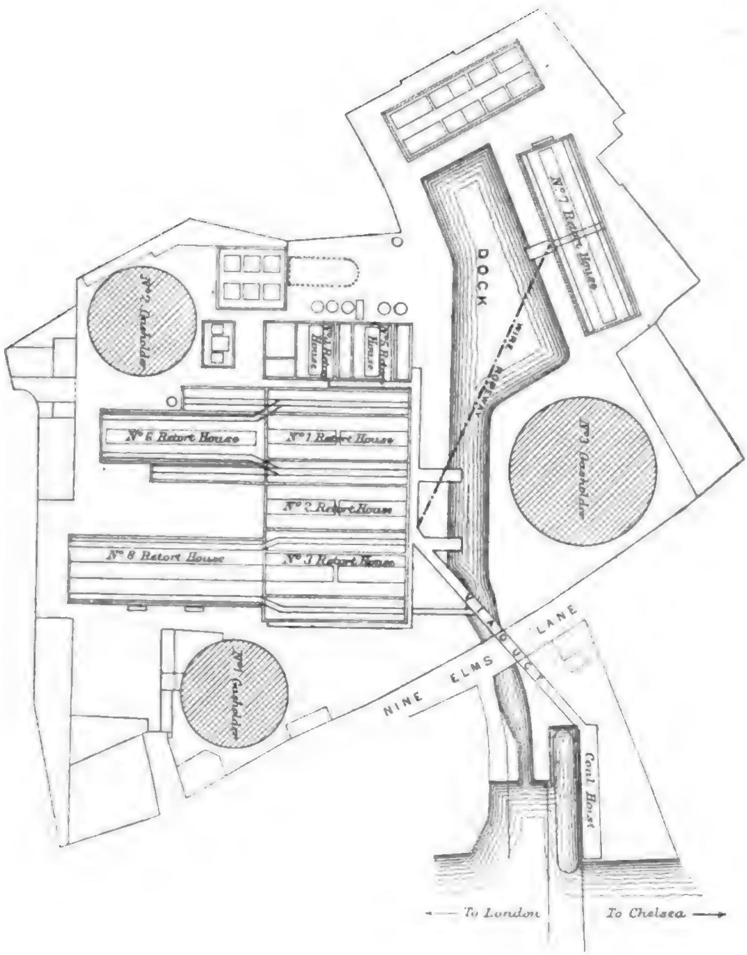
which they revolve; they are worked from the level of the platform, the lifting and slewing-cylinders, valves, &c., being suitably housed underneath. The quantity raised at each lift is 13·3 cwt., the gross weight being about 18½ cwt.; and 1,000 tons can be dis-



RIVER THAMES

charged in seven hours, the average lift being about 48 feet. Over the platform, and at a sufficient height to admit of the trucks passing under them, are fixed two wrought-iron hoppers capable of holding 400 tons of coal, and into these the coal from the cranes

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is tipped; they are provided with sliding doors underneath, so arranged that one man can load a truck with 33 cwt. of coal in a few seconds; the construction of the hoppers is such that they almost clear themselves without trimming. The loaded trucks are pushed by hand on to the weigh-bridge already mentioned, where they are weighed, and from whence they are taken by an endless overhead chain into the works to be distributed; this chain is driven by a small hydraulic capstan, whose diameter coincides with the distance, from centre to centre, of the two lines of rail on the viaduct, and is utilized in bringing back the empty trucks. On the wharf, at the head of the ships' berth, is placed a powerful hydraulic capstan for use in getting the ships into position.

It only remains to say that the boilers, engines and pumps are in duplicate, and are placed conveniently in suitable rooms under the platform. The engines are vertical, with double cylinders, one set being high pressure, the other compound-condensing; the pumps run tandem with the cylinders and are driven direct from the piston-rods. Steam is used, instead of a dead weight, to accumulate pressure in the ram-cylinder, and the large steam-cylinder employed for this is made to serve the purpose of a bed-plate for the engines and pumps. The boilers are of both Cornish and locomotive construction, and are worked at a pressure of from 70 to 80 lbs., the water-pressure being 700 to 800 lbs. per square inch.

This Paper is accompanied by a plan, from which the woodcut in the text has been engraved, and by four photographs.

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(*Paper No. 2002.*)

"Lighthouse-Apparatus for Dipping-Lights."

By Alan Brebner, Jun., B.Sc., Assoc. M. Inst. C.E.

The change herein proposed in the form of optical apparatus for lighthouses is to improve their useful illuminating power during hazy weather, without diminishing their efficiency under ordinary atmospheric conditions. The desirability of some such change has been pointed out by Mr. T. Stevenson,[1] and the one to be now described retains, along with the refracting drum, the reflecting prisms adopted by Fresnel for reasons enumerated by Mr. J. T. Chance.[2]

In its most efficient form, the change consists in reducing the upper cupola, prisms and metallic framework included, to the same weight as the refracting drum, prisms and metallic framework included; in suspending the former in counterpoise against the latter by means of pulleys and chains, the pulleys being carried by steel standards which rest upon the framework of the lower reflecting prisms. The latter prisms remain, like the luminary, constant in position. The pulley axle-bearings are subjected to a pressure due to the combined weights of the upper cupola and refracting-drum, and the force required simultaneously to lower the latter and raise the former is sensibly that which suffices to overcome frictional resistance at these bearings. The matter will be most readily understood by an inspection of Plate 14, Figs. 1, 2 and 3. In normal conditions all the refracting prisms but two combine with all the lower reflecting prisms to direct the best part of the light incident on them towards the sea horizon; but the upper reflectors direct the light that falls on them with more and more of dip, or less and less of range, as one passes from

[1] "It always appeared to me that, had we an easy way of doing so, we ought to increase temporarily the dip of the light, and thus, during haze and fogs, to direct the strongest beam to a point much nearer the shore than the sea horizon." T. Stevenson, "Lighthouse Construction and Illumination," 1881, p. 237.

[2] "There is a limit beyond which prismatic deflection becomes wasteful, partly by chromatic dispersion, and partly from the increasing loss by reflection at the surfaces of incidence and emergence. It occurred to Fresnel to adopt totally-reflecting zones." J. T. Chance, in Minutes of Proceedings Inst. C.E. vol. xxvi., 1866–67, p. 487.

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the lowest to the highest. This distribution, it will be observed, is in harmony with the requirements of the case, light of less intensity being directed to less distant positions. The two lowermost refracting prisms, although farther removed from the horizontal focal plane than any of the upper refracting prisms, are not less favourably situated with respect to losses of light by surface reflection and dispersion, since less deviation is demanded of them; they take up the duty of lighting the approaches to the lighthouse where the upper reflecting prisms leave it off.

This normal light-distribution is particularly suitable for small luminaries such as electric light, the apparatus now effecting what is left, when oil or gas flames are used, to be performed by one half of the ex-focal rays, the other half being skied. With an alternative-current electric luminary the proportion of light directed skywards by the refracting prisms can always be reduced to one quarter, namely, that proceeding from the lower half of the brightly incandescent portion of the lower carbon, for that of the upper half of the lower carbon going to the horizon the whole of the light from the upper carbon necessarily falls on the sea between the horizon and the lighthouse tower.

For the upper and lower prisms respectively the same luminary will act as a single light source, and by a judicious selection of the positions of the foci for calculation, and a careful adjustment, no light need be skied by the upper reflectors as arranged in the design, Plate 14, Fig. 1, while at least one half of the light incident on the lower reflectors should be utilized.

In Plate 14, Fig. 2, which represents the light distribution during decided haze, and in which the displacement is supposed to equal 50 millimetres downwards and upwards for the refractor and the upper cupola respectively, all the light of the upper reflectors (except that of the two lowest and supplementary ones, which give 4° of dip to light that but for their presence would be lost skywards), is dipped to the extent of 3°; the focal rays from the refractor are dipped from 4° 46′ at the central belt to 4° 12′ at the ninth above and below it, while the normal dip of the tenth and eleventh below is increased about 4° 12′. Lastly, in this light-distribution for haze the light from the lower reflectors goes as previously towards the horizon; and this is of no little importance for such occurrences as a sudden rise of mist, or partial mists that do not surround the lighthouse towards all points of the compass. It may be said roughly that this lower-reflector light, being about one-tenth of the whole, would, in the case of an ordinary fixed-light apparatus for the electric light, continually direct

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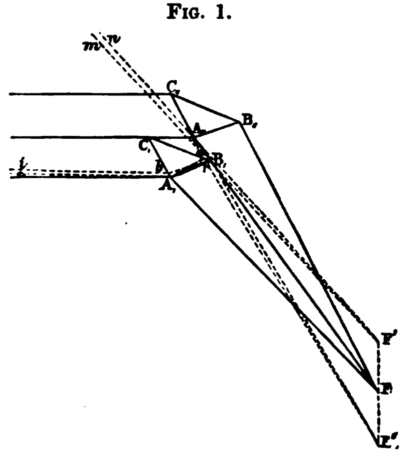
light to the horizon of an intensity equal to that obtained from the entire apparatus in combination with the best oil or gas flames.

Evidently the movable parts of the apparatus are capable of being adjusted to any intermediate position between the normal and decided haze positions, if in any cases such an intermediate position may be called for, and shall not cause too great complication in the service of the lights.

In apparatus disposed as above the dimensions of the upper reflecting prisms have to be reduced in order to arrive at equality of weight between the upper cupola and the refracting-drum. This reduction increases the optical efficiency by diminishing the amount of absorption in the mass of the prisms.

It must further be noted that in order to render the upper reflectors as efficient as those hitherto used in catching the light directed towards them, a change is necessary in the determination of their profiles. Figs. 1 and 2 will illustrate this. In Fig. 1 F represents the focus, and $A_{/}$ $B_{/}$ $C_{/}$, $A_{//}$ $B_{//}$ $C_{//}$ two adjacent prisms calculated in the usual way so as to avoid superfluous glass, and so that the ray F $B_{//}$ travels along $B_{//}$ $A_{//}$ in the prism, and passes out along $A_{//}$ $C_{/}$ grazing past the corner $C_{/}$ of the underlying prism, while the ray F $A_{//}$ similarly grazes past $B_{/}$ the innermost corner of the underlying prism. Since in this new form of apparatus, however, the position of the focus F varies relatively to that of the reflecting prisms, there would result, if the usual profiles were employed, a loss of the angle of light *m* F′ *n* if the focus were relatively higher and at F′, and a loss of the angle of light *r* F″$B_{//}$ which would be directed skywards, if the focus F were relatively lower and at F″. To avoid such losses a simple device is resorted to, which adds no complication to the mode of constructing the catadioptric prisms.

FIG. 1.



This device (Fig. 2, which is on a scale of $\frac{1}{3}$ of the fifth above the lowest catadioptric prism in the cupola, Plate 14, Fig. 1)

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consists in determining the direction to be given to the reflected light during haze (3° below the horizon in the design, Plate 14, Figs. 1 and 2); in assuming as the focus of calculation for the prisms of the cupola a point F′ lower than the normal horizontal focal plane of the refractor, by an amount equal to the maximum lowering to be given to the refractor, or rise to be given to the upper cupola (50 millimetres in the design, Plate 14, Figs. 1 and 2); in determining by the ordinary formulas the profile C A B, so as in the present instance to emit the light coming from F′ with a dip of 3°; and in producing B A, and the curved side B C so far that the ray F $a_{,,}$ which, coming from the normal focal position, clears the underlying prism and follows the path $a_{,}$ c in the glass, may meet the reflecting side of the prism, and be properly acted on by it. The position of B′, and the relative difference of position between F and F′ being known, c can be determined, and to obtain the required profile c a is drawn from c parallel to C A. The result is that in normal conditions the extreme focal rays falling on the prism follow the paths F B $c_{,,}$ $b_{,}$ and F $a_{,}$ c $d_{,}$, whilst on changing the position of the apparatus during haze, the extreme focal rays follow the paths F′ B a b and F′ A C $c_{,}$ d.

Fig. 2.

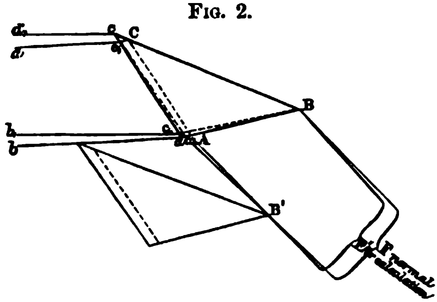

Plate 14, Figs. 4, 5, 6, which are on a scale of $\frac{1}{5}$, show the manner in which it is proposed to hang the upper cupola in equilibrated counterpoise against the refracting-drum. The estimated weights in the movable portion of the apparatus, Plate 14, Fig. 1, are:—

—	Weight of Glass.	Weight of Metal.	Total Weight.
	Kilos.	Kilos.	Kilos.
Upper cupola . . .	181	100	281
Refracting-drum . .	188	98	286

The weight of the whole movable portion of the apparatus would thus be 567 kilograms, therefore 113·4, or 94·5 kilo-

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grams per pulley, according as five or six pulleys were used. The difference of 5 kilograms in the estimated weights of the two parts in counterpoise being much inferior to the weight of 50 or 60 kilograms which should have to be added to either, in order to move the whole movable portion, is considered slight enough to allow of the use of the expression "equilibrated counterpoise."

It will be seen in Plate 14, Figs. 1 and 3, that in order to provide for the entrance into the apparatus of the lightkeepers and of the lamp, one of the six pulleys placed at angular distances of 60° round the vertical focal axis has been suppressed, that an opening of sufficient breadth for the entrance of a lamp has been left in the refracting drum, and that a 60° panel of lower reflecting prisms has been suppressed. Thus only the upper cupola is complete. The vertical settings of the refracting-drum which face each other on opposite sides of the opening in the same can, however, be connected by metallic bars mounted on hinges, so as to reduce the refracting drum, except at the moments of entering or withdrawing lamps, to a rigid cylindrical body. The suppressed lower reflector panel may also be restored, if desired, in the form of a hinged door. Further, the suppression of one of the pulleys may be avoided, if certain rules as to the mode of entering the lamps, or as to the form of the same be adopted.

The precise mode of changing the position of the movable portion of the new form of apparatus above described, and of other less perfect forms of it, will depend greatly on the circumstances of each case; in general terms, however, the movements shall be obtained by aid of levers, of weights, of multiplying teethed wheel-gearing, of springs, &c., controlled by muscular, steam, or other power. If a lever be used for an apparatus such as that shown by Plate 14, Fig. 1, its fulcrum will probably be most conveniently attached to the dome of the lantern; if teethed wheel-gearing be used, the movement may be applied to the upper bronze ring of the upper cupola of reflecting prisms.

In this Paper the case of a fixed-light apparatus only has been dealt with, but the invention is applicable to revolving light apparatus also. It has been patented by Messrs. Barbier and Fenestre, of Paris, under whose patronage the study of it has been carried out.

The Paper is illustrated by three tracings, from which Plate 14 and the woodcuts in the text have been prepared.

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(*Paper No. 1974.*)

"The Sewering of Towns on the Separate System.—Size and Inclination of Sewers."

By Alfred Edward White, Assoc. M. Inst. C.E.

There is no doubt that each of the two systems of sewerage, the separate and the combined, possesses certain advantages and certain disadvantages, as compared with the other; there being some conditions under which the former system may be adopted with the greater benefit, and other conditions under which the latter is the more applicable. An advantage of some importance, however, which the separate system possesses over the combined system, is that of allowing of the use of sewers of a smaller size.

As a rule the smaller a sewer (within certain limits) the better, provided it is large enough to deliver the maximum quantity required to be disposed of; and the smaller the excess of the maximum flow over the ordinary flow, the more efficient may the sewer be made for the conveyance of the ordinary flow. A sewer constructed to receive the whole of the surface water in addition to the sewage, will not, with the dry-weather flow consisting of sewage only, work as efficiently as a smaller sewer, constructed to convey the sewage with only a limited quantity of surface water. The larger sewer is so much in excess of the requirements of the dry-weather flow, that it will not under ordinary circumstances be self-cleansing to the same extent as the smaller sewer, while the smaller may also be more efficiently flushed with a moderate supply of water.

It probably is necessary in almost all cases (in order to avoid an unreasonably complicated arrangement of branch drains) to admit the water from back roofs and back yards to the sewers, even where there are separate drains for surface water; but the greater the quantity so admitted the more it will tend to neutralize the advantage above referred to.

To determine the volume of the dry-weather flow in any sewer is a comparatively simple matter, if sewage only be admitted to it,

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as such volume may be considered equal to the amount of the water-supply; which amount is usually known with sufficient accuracy, and for an average town may be taken at 25 gallons per head per day. In making provision for the maximum dry-weather flow of sewage, it is usual to assume that one-half the daily quantity is discharged in from six to eight hours; if therefore the daily quantity be assumed at 25 gallons per head, the maximum flow will be at the rate of 12½ gallons per head in (say) six hours, or about 2 gallons per head per hour.

The amount of rainfall, which it is necessary to provide for in the sewers, is a much more difficult matter to determine, and one which seems to be often under-estimated. In the first place it is necessary to estimate the amount which the sewers should be capable of receiving above storm-overflows; and in the second place the amount which they should deliver below such overflows. To prepare for the heaviest rains in this country is out of the question, considering the excessive falls which occasionally take place. The rate of rainfall to be provided for above the overflows should be determined with due regard to the degree of risk of such rate being exceeded, and to the amount of inconvenience or damage which would be caused in the event of its being exceeded; but to incur a great expense in constructing large sewers, merely to avoid the probability of their overflowing and causing a small amount of damage, once or twice in a generation, would be unreasonable. Such expense, however, might be justified where the probability of overflow, and also the damage likely to ensue, were great. With regard to the sewers below storm-overflows, their capacity should be sufficient to avoid overflows of such frequency and amount, as would seriously pollute the watercourses or rivers receiving the overflows.

Under the separate system the only rain which should find its way to the sewers is that falling upon back roofs and back yards, and the quantity may be estimated from the area of such roofs and yards, together with the maximum rate at which rain falls. The above area may be taken at an average of 500 square feet for a house occupied by five persons, or 100 square feet per head of the population, and it may be assumed that the entire rainfall upon such area is discharged into the sewers.

The published rainfall-tables, of the description required to determine the maximum rate at which there is a probability of rain falling, are of a very meagre character. Observations of rainfall are not usually taken at shorter intervals than twenty-four hours, and the duration and amount of most heavy rains con-

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sequently are not recorded. In the volumes of "British Rainfall,"[1] there are, however, Tables giving all the exceptionally heavy falls reported by observers in various parts of the United Kingdom, and by these Tables some valuable information on the subject is given. Taking the records of the three years, 1880, 1881 and 1882; there are reported fifty-seven falls at a rate of over 1 inch per hour, forty-two over 1¼ inch, thirty over 1½ inch, eighteen over 2 inches, six over 3 inches, and two over 5 inches per hour. The heaviest fall reported was at the rate of 5·80 inches per hour, and it continued for thirty minutes. Regarding these records, the impracticability of providing for the heaviest falls is obvious; it seems to the Author, however, that a fall at the rate of 1¼ inch per hour should in average cases be provided for, in sewers which are not relieved by storm-overflows; and for the purpose of future calculations it is assumed that such sewers should be capable of receiving a fall of this amount. It should be stated that many of the above-mentioned forty-two falls, which exceeded 1¼ inch per hour, were of such short duration that they would not cause sewers, capable of discharging this amount, to overflow, as the capacity of sewers, independent of their discharging power, is considerable.

The available statistics, of the character necessary to determine the amount of rainfall which it is desirable to provide for in sewers below storm-overflows, are, for the purpose required, of a more satisfactory nature than those above referred to. "British Rainfall" for the year 1880 contains a very useful Table, contributed by Mr. Baldwin Latham, M. Inst. C.E., prepared from the records of a self-recording rain-gauge at Croydon; such Table giving the quantity, duration, and rate per twenty-four hours, of all falls of rain of any importance, from March 1879 to April 1881. Some similar information is afforded by the records of a self-recording rain-gauge at Camden Square, London, which have very kindly been placed at the disposal of the Author by Mr. Symons. As these records have not before been tabulated, a Table prepared from them, giving particulars of the important falls of 1881 and 1882, is appended to this Paper.

Table 1, which is an abstract from the above-mentioned Tables, shows the number of times certain rates of rainfall were exceeded in two years; also the aggregate duration of the falls exceeding these rates.

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[1] "On the distribution of Rain over the British Isles." Compiled by G. J Symons, F.R.S.

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TABLE 1.

—	Rate of Fall in fractions of an inch per hour.	Number of times rate was exceeded in two years.	Aggregate duration of excessive falls in hours.
Croydon Records	$\frac{1}{4}$	38	$20\frac{1}{4}$
	$\frac{1}{6}$	78	45
	$\frac{1}{8}$	108	73
	$\frac{1}{12}$	154	$115\frac{1}{2}$
Camden Square Records	$\frac{1}{4}$	59	$11\frac{1}{2}$
	$\frac{1}{6}$	99	$35\frac{3}{4}$
	$\frac{1}{8}$	136	$71\frac{3}{4}$
	$\frac{1}{12}$	202	119

From this Table may be obtained, approximately, the number of times that storm-overflows would come into action with sewers capable of discharging various amounts of rain, and also the aggregate duration of the overflows. As, however, a number of the falls included were of very short duration, and in many cases would not be simultaneous over the whole drainage area, it may be assumed that some of them would not cause overflows, and that the duration of the overflows caused by others would be reduced; and to compensate for this a deduction of (say) 20 per cent. should be made from the figures in Table 1. Now, taking a sewer capable of discharging a rainfall of $\frac{1}{8}$ inch per hour, and making the required deduction, the number of overflows during two years, according to the Croydon records, would be eighty-six, and according to the Camden Square records one hundred and nine, and their aggregate duration, in each case, about fifty-eight hours; or during one year the number of overflows would be forty-three and fifty-four and a half respectively, and their duration, in each case, about twenty-nine hours. Overflows to this extent in most cases, and probably to a considerably greater extent in many cases, would be admissible, and for the purpose of future calculations it is therefore assumed that sewers below storm-overflows should be capable of discharging $\frac{1}{8}$ inch of rainfall per hour.

It is of interest to notice that of the rainfalls at Croydon and Camden Square, during the above period, none amounted to the maximum quantity which would be received by sewers capable of discharging $1\frac{1}{4}$ inch per hour. Eight falls were in excess of one-half the capacity of such sewers, forty-six of one-quarter, and one hundred and sixty-eight in excess of one-

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eighth their capacity. The heaviest fall, which was at Camden Square, continued for ten minutes at the rate of 1·68 inch per hour; this, however, taking into consideration the shortness of its duration, was about 12 per cent. below that which sewers capable of discharging 1¼ inch per hour would receive. The fall second in importance was at Croydon, and continued for ten minutes at the rate of 1·34 inch per hour, this being about 30 per cent. below the amount the sewers would receive.

Upon the area before mentioned as that which may be assumed to be covered, per head of the population, by back roofs and yards, viz., 100 square feet, a rainfall of 1¼ inch would produce 65 gallons; and as the maximum volume of the sewage proper, in average cases, as already determined, is about 2 gallons per head per hour, a total of 67 gallons per hour should be provided for in sewers which are not relieved by storm-overflows. With regard to sewers below storm-overflows, the volume to be provided for, per head per hour, according to the foregoing conclusions, is a rainfall of ⅛ inch on 100 superficial feet, or 6½ gallons, and 2 gallons of sewage, making 8½ gallons.

Sewers should, where possible, be constructed with such inclinations as will render them self-cleansing with the ordinary flow of sewage; and where this is impracticable, the inclination should at least be sufficient to give a self-cleansing velocity with the assistance of flushing.

As to the velocity necessary for self-cleansing purposes, authorities differ somewhat. It seems to be usually considered that small sewers require a greater mean velocity of sewage flow than large sewers, but the grounds upon which this assumption is based do not seem very clear. The bottom-velocity is that upon which the self-cleansing properties depend; but how is this velocity to be determined? The size, form, gradient, and depth of flow of a sewer being given, there are several reliable formulas for calculating the mean velocity, but not so the bottom-velocity. One authority states the bottom-, mean, and surface-velocities to be nearly as 3, 4, and 5, and others express the ratio by figures nearly corresponding with these. It appears to be assumed that these proportions apply under all circumstances; but that this is a mistaken assumption, the Author would submit, may be proved as follows:—

If a trough be taken, as shown by the annexed diagram, in which the water is up to A, then, according to the above rule, if the velocity of flow at A be represented by 5, that at B, half-way down, will be about 4, and at the bottom 3, while the velocity at C, mid-way

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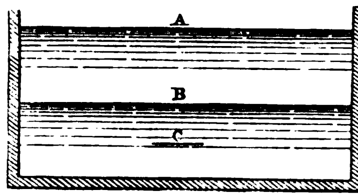
between the bottom and B, will be about 3½. Now if the water be only up to B—that is to say, of half the depth before assumed—and the inclination be increased so that the mean velocity is the same as before, then the velocity at C, it being about the mean, will be 4. Thus in the former case the velocity at C, which



was 3½, was less than in the latter, the mean velocity in each case being the same. How then will the bottom velocities in the two cases correspond? The velocity of the bottom-water is affected by three forces: 1. Its own gravity, due to the inclination of the trough. 2. The velocity of the water directly above. 3. Its friction upon the bottom of the trough. The first force, that of gravity, is greater in the latter case, or with the shallow flow, as the inclination is greater; the second force, that of the water above, is also greater in the latter case, for, taking any point above the bottom, as for instance the point C, the velocity at that point is greater in the shallow flow. The third force, that of friction, upon the bottom of the trough, is equal in each case. Both the force of gravity, and the greater velocity of the water above, tend to give the bottom-water a greater velocity with the shallow flow, and it is therefore evident that the difference between the mean and the bottom velocity is greater with a deep flow of sewage than with a shallow flow, or, under ordinary circumstances, with a large sewer than with a small one. It would therefore appear that the mean velocity necessary to render sewers self-cleansing is greater with a deep flow than with a shallow flow.

It may be assumed that 150 feet per minute is an ample self-cleansing velocity for ordinary sewers when running half-full or thereabouts, and 135 feet per minute is probably quite sufficient for a shallow flow, such as that discharged in dry weather, provided the sewage be sufficiently deep to float or submerge the solid matters contained in it.

The inclinations necessary to produce a velocity of 150 feet per minute in circular sewers of various sizes, flowing half-full, or full, and in egg-shaped sewers flowing two-thirds their vertical height, are shown in Table 2; also the population which such sewers,

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when running full, would be capable of serving at 67 gallons per head per hour above storm-overflows, and $8\frac{1}{2}$ gallons below storm-overflows.

TABLE 2.

Size of Sewer.	Inclination to produce velocity of 150 feet per minute.	Population served by sewers above storm-overflows.	Population served by sewers below storm-overflows.
Ft. Ins. Ft. Ins. 0 6 diameter	1 in 174	165	1,297
0 9 „	„ 261	370	2,919
1 0 „	„ 349	658	5,189
1 3 „	„ 436	1,028	8,107
1 6 „	„ 524	1,481	11,675
2 3 × 1 6	„ 661	2,080	16,390
2 6 × 1 8	„ 734	2,567	20,235
2 9 × 1 10	„ 808	3,106	24,485
3 0 × 2 0	„ 882	3,697	29,140
3 3 × 2 2	„ 955	4,340	34,200

Sewers should not be constructed to flatter inclinations than the above, and these inclinations are only admissible where flushing-power is provided.

In the preparation of the foregoing and following Tables, the formulas used are those of Eytelwein, viz.:—

$$V = 5604 \sqrt{R\,S}.$$

$$S = \frac{V^2}{R\,(5604)^2}.$$

where V = velocity in feet per minute.
S = sine of inclination.
R = hydraulic radius.

To ascertain the gradients required for self-cleansing with the dry-weather flow, it is necessary to determine the amount of such flow as compared with the capacity of the sewers. According to the figures already given, the maximum quantity to be provided for in sewers above storm-overflows is $33\frac{1}{2}$ times, and in sewers below storm-overflows $4\frac{1}{4}$ times, the maximum dry-weather flow. The difference, however, between the dry-weather flow and the capacity of the sewers would often be considerably greater than this, as sewers are of necessity somewhat larger than necessary for the maximum flow, through certain portions of their length, especially on approaching dead ends. To allow the required margin,

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let it be assumed that the capacity of sewers above storm-overflows is 45 times, and below storm-overflows 5 times, the maximum dry-weather flow. Working upon these proportions, the inclinations required above storm-overflows in sewers of various sizes, to produce a velocity of 135 feet per minute with the dry-weather flow, are shown by Table 3; also the depth of the dry-weather flow, the assumed population contributing to it, the velocity when running full, and the population which the sewers, when running full, would be capable of serving, at 67 gallons per head per hour.

TABLE 3.

Size of Sewer.	Inclination to produce velocity of 135 feet per minute, with maximum dry-weather flow.	Depth of dry-weather flow, or of flow equal to one forty-fifth the capacity of sewer.	Population contributing to dry-weather flow.	Velocity when running full in feet per minute.	Population served by sewer when running full at 67 gallons per head per hour.
Ft. Ins. Ft. Ins.		Inch.			
0 6 diam.	1 in 50	0·56	230	280	308
0 9 „	„ 75	0·83	514	„	691
1 0 „	„ 100	1·11	915	„	1,229
1 3 „	„ 125	1·39	1,428	„	1,919
1 6 „	„ 150	1·67	2,057	„	2,764
2 3 × 1 6	„ 214	2·63	2,708	252	3,638
2 6 × 1 8	„ 238	2·92	3,343	„	4,491
2 9 × 1 10	„ 262	3·21	4,046	„	5,435
3 0 × 2 0	„ 286	3·50	4,816	„	6,468
3 3 × 2 2	„ 310	3·79	5,650	„	7,590

Table 4 gives particulars, similar to those in the preceding Table, with reference to sewers below storm-overflows, the maximum flow being taken at 8½ gallons per head per hour.

TABLE 4.

Size of Sewer.	Inclination to produce velocity of 135 feet per minute, with maximum dry-weather flow.	Depth of dry-weather flow, or of flow equal to one-fifth the capacity of sewer.	Population contributing to dry-weather flow.	Velocity when running full in feet per minute.	Population served by sewer when running full at 8½ gallon per head per hour.
Ft. Ins. Ft. Ins.		Inch.			
0 6 diam.	1 in 145	1·76	1,213	165	1,427
0 9 „	„ 217	2·64	2,729	„	3,211
1 0 „	„ 289	3·52	4,852	„	5,708
1 3 „	„ 361	4·40	7,581	„	8,919
1 6 „	„ 434	5·28	10,917	„	12,843
2 3 × 1 6	„ 525	8·79	15,577	161	18,326
2 6 × 1 8	„ 583	9·77	19,231	„	22,625
2 9 × 1 10	„ 642	10·75	23,270	„	27,377
3 0 × 2 0	„ 700	11·72	27,693	„	32,580
3 3 × 2 2	„ 758	12·70	32,502	„	38,237

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The difference shown in Tables 3 and 4 between the population contributing to the dry-weather flow, and the population which the sewers are capable of serving, represents the margin allowed in determining the amount of the dry-weather flow, as compared with the maximum flow, as previously explained. Should the population contributing to the dry-weather flow be less than that stated, in which case the volume of sewage would also be less, an increased inclination would be required to give the self-cleansing velocity.

The size of sewer for inclinations other than those in the Tables may easily be calculated from those given, the discharge being in proportion to the square root of the sine of the inclination. The size, however, for a given population and given inclination, may vary considerably, according to the local conditions affecting the volume of sewage per head to be disposed of.

With sewers on the combined system, the maximum amount of water to be dealt with, in proportion to the population, would probably be, in an average case, three times that provided for in the Tables; and the population served by a sewer of a given size would consequently be proportionately less.

The Paper is accompanied by a diagram, from which the wood cut in the text has been prepared.

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APPENDIX.

Rainfall at Camden Square, London, 1881 *and* 1882.

Table prepared from records taken by Mr. G. J. Symons, F.R.S., Past-President of the Meteorological Society, from a self-recording rain-gauge; giving quantity, duration, and rate per hour of falls exceeding 0·03 inch in quantity, and 0·08 inch in rate of fall per hour.

Date.	Quantity of rain falling.	Duration of fall.	Rate of fall per hour.	Date.	Quantity of rain falling.	Duration of fall.	Rate of fall per hour.	Date.	Quantity of rain falling.	Duration of fall.	Rate of fall per hour.
1881.					In.	Min.	In.		In.	Min.	In.
	In.	Min.	In.	Aug. 1	0·11	50	0·13	Oct. 13	0·42	200	0·13
Feb. 7	0·23	60	0·23	,, 8	0·56	145	0·23	,, 15	0·06	5	0·72
,, 9	0·06	30	0·12	,, 8	0·08	20	0·24	,, 22	0·09	20	0·27
Mar. 3	0·08	35	0·14	,, 12	0·36	85	0·25	,, 22	0·08	25	0·19
,, 4	0·04	25	0·10	,, 16	0·05	15	0·20	,, 22	0·06	20	0·18
,, 4	0·04	25	0·10	,, 17	0·09	5	1·08	,, 22	0·37	120	0·18
,, 4	0·14	64	0·13	,, 17	0·04	4	0·60	,, 23	0·08	25	0·19
,, 5	0·06	40	0·09	,, 17	0·06	38	0·09	Nov. 2	0·06	35	0·10
,, 5	0·28	110	0·15	,, 17	0·06	35	0·10	,, 11	0·04	20	0·12
,, 7	0·04	5	0·48	,, 21	0·10	30	0·20	,, 16	0·06	40	0·09
,, 7	0·04	25	0·10	,, 21	0·06	12	0·30	,, 16	0·10	30	0·20
,, 7	0·04	20	0·12	,, 21	0·20	20	0·60	,, 20	0·09	30	0·18
May 2	0·08	40	0·12	,, 21	0·05	10	0·30	,, 20	0·05	32	0·09
,, 18	0·05	35	0·09	,, 23	0·05	35	0·09	,, 25	0·04	22	0·11
,, 26	0·08	15	0·32	,, 23	0·18	50	0·22	,, 26	0·05	30	0·10
,, 26	0·04	10	0·24	,, 23	0·04	20	0·12	,, 26	0·12	7	1·03
,, 28	0·28	10	1·68	,, 23	0·07	20	0·21	,, 26	0·07	40	0·10
,, 28	0·15	45	0·20	,, 25	0·12	65	0·11	,, 27	0·07	10	0·42
June 5	0·08	45	0·11	,, 29	0·23	75	0·18	,, 30	0·04	25	0·10
,, 5	0·08	50	0·10	,, 29	0·05	12	0·25	Dec. 5	0·18	85	0·13
,, 5	0·06	20	0·18	,, 29	0·05	10	0·30	,, 6	0·06	15	0·24
,, 6	0·20	55	0·22	,, 29	0·07	10	0·42	,, 16	0·06	20	0·18
,, 6	0·08	45	0·11	,, 29	0·06	35	0·10	,, 17	0·12	70	0·10
,, 17	0·04	12	0·20	,, 29	0·10	16	0·38	,, 17	0·05	5	0·60
,, 17	0·15	20	0·45	,, 30	0·18	18	0·60	,, 17	0·10	60	0·10
,, 17	0·14	65	0·13	Sept. 5	0·22	80	0·17	,, 17	0·09	7	0·77
,, 25	0·20	125	0·10	,, 6	0·04	15	0·16	,, 17	0·04	12	0·20
July 5	0·08	50	0·10	,, 20	0·12	25	0·29	,, 19	0·13	25	0·31
,, 5	0·05	10	0·30	,, 20	0·17	10	1·02				
,, 5	0·06	5	0·72	,, 22	0·04	27	0·09				
,, 5	0·10	7	0·86	,, 22	0·04	17	0·14	1882.			
,, 5	0·12	12	0·60	,, 24	0·04	12	0·20	Jan. 1	0·20	115	0·10
,, 6	0·18	13	0·83	,, 24	0·04	15	0·16	,, 8	0·08	30	0·16
,, 8	0·05	10	0·30	,, 24	0·10	35	0·17	,, 8	0·09	10	0·45
,, 12	0·04	15	0·16	,, 24	0·18	70	0·15	,, 8	0·08	30	0·16
,, 28	0·22	105	0·13	Oct. 7	0·04	15	0·16	,, 8	0·04	25	0·10
,, 28	0·04	25	0·10	,, 7	0·07	40	0·11	,, 29	0·11	50	0·13
,, 30	0·06	8	0·45	,, 7	0·11	50	0·13	Feb. 13	0·06	30	0·12
,, 31	0·11	55	0·12	,, 8	0·10	30	0·20	,, 14	0·06	35	0·10

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Date.	Quantity of rain falling.	Duration of fall.	Rate of fall per hour.	Date.	Quantity of rain falling.	Duration of fall.	Rate of fall per hour.	Date.	Quantity of rain falling.	Duration of fall.	Rate of fall per hour.
	In.	Min.	In.		In.	Min.	In.		In.	Min.	In.
Feb. 14	0·14	15	0·56	June 24	0·08	22	0·22	Sept. 5	0·05	15	0·20
,, 14	0·06	30	0·12	July 5	0·12	12	0·60	,, 5	0·06	25	0·14
Mar. 1	0·08	5	0·96	,, 5	0·04	4	0·60	,, 5	0·06	30	0·12
,, 2	0·07	15	0·28	,, 5	0·07	6	0·70	,, 5	0·11	50	0·13
,, 25	0·20	130	0·09	,, 6	0·04	15	0·16	,, 11	0·07	45	0·09
,, 25	0·08	6	0·80	,, 6	0·04	7	0·34	,, 14	0·10	28	0·21
,, 25	0·08	45	0·11	,, 8	0·07	22	0·19	,, 28	0·67	300	0·13
,, 30	0·04	15	0·16	,, 8	0·12	8	0·90	Oct. 2	0·12	25	0·29
Apr. 12	0·04	15	0·16	,, 9	0·08	10	0·48	,, 15	0·12	80	0·09
,, 13	0·04	15	0·16	,, 10	0·09	17	0·32	,, 15	0·04	22	0·11
,, 13	0·06	35	0·10	,, 10	0·26	20	0·78	,, 16	0·06	40	0·09
,, 22	0·18	100	0·11	,, 10	0·07	10	0·42	,, 19	0·10	40	0·15
,, 23	0·10	8	0·75	,, 10	0·24	13	1·11	,, 21	0·04	20	0·12
,, 25	0·40	175	0·14	,, 10	0·05	20	0·15	,, 21	0·10	65	0·09
,, 25	0·08	25	0·19	,, 10	0·04	8	0·30	,, 21	0·13	70	0·10
,, 25	0·12	65	0·11	,, 10	0·04	8	0·30	,, 21	0·07	6	0·70
,, 27	0·09	35	0·15	,, 11	0·04	20	0·12	,, 23	0·43	205	0·13
,, 29	0·04	15	0·16	,, 11	0·04	15	0·16	,, 24	0·12	50	0·14
,, 30	0·04	15	0·16	,, 17	0·04	23	0·10	Nov. 2	0·08	5	0·96
May 3	0·09	20	0·27	,, 18	0·04	20	0·12	,, 6	9·04	20	0·12
,, 5	0·04	25	0·10	,, 24	0·06	8	0·45	,, 7	0·23	55	0·25
,, 5	0·21	90	0·14	,, 24	0·11	10	0·66	,, 18	0·10	27	0·22
,, 25	0·14	70	0·12	Aug. 22	0·20	45	0·27	,, 18	0·04	22	0·11
June 4	0·16	10	0·96	,, 22	0·04	17	0·14	,, 28	0·06	25	0·14
,, 6	0·05	15	0·20	,, 24	0·04	12	0·20	Dec. 25	0·04	20	0·12
,, 8	0·08	45	0·11	,, 26	0·05	27	0·11	,, 25	0·04	25	0·10
,, 9	0·04	8	0·30	,, 28	0·07	8	0·52	,, 25	0·08	40	0·12
,, 9	0·06	5	0·72	,, 29	0·07	22	0·19	,, 31	0·05	30	0·10
,, 9	0·12	30	0·24	Sept. 1	0·05	30	0·10	,, 31	0·12	27	0·27
,, 24	0·23	80	0·17	,, 5	0·05	25	0·12				

NOTE.—It should be mentioned that the above Table is not quite complete, as, in consequence of frost and other causes, there were a number of days during the two years upon which no records were taken; this occasional omission of records, however, cannot materially have affected the accuracy of the Table.

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(*Students' Paper No. 180.*)

"On the Electric Light."[1]

By Alfred Richard Sennett, Stud. Inst. C.E.

The production of electricity, and its subsequent conversion into light, is to-day another example of "directing the great sources of power in nature for the use and convenience of man," and, as such, falls within the category of works undertaken by the Civil Engineer. It is the purport of the Author briefly to explain in what electric lighting consists, the relation which it bears to other methods of illumination, and to describe some of the apparatus employed in its production and utilization. Electric lighting, then, consists in converting energy, whether potential or kinetic, into light through the intervention of that form of energy known as electricity. This transmutation by the ordinary method, namely, by employing a steam-engine to give motion to a magneto- or dynamo-electric generator, is somewhat exceptional. Nevertheless, although the best engines yield but about one-ninth part of the total energy residing in the coal consumed, and loss may and does take place in the transmission of the kinetic energy of the motor to the generator,—in this latter in the transport of the electric energy to the focus of illumination, and, indeed, at the focus itself,—yet in point of economy it compares most favourably with all other methods of illumination. The only reason which can be given for this is, that through the agency of electricity a greater concentration of heat can be effected than by any other means, and because the intensity of the light emitted from an incandescent body rises much more rapidly than the temperature. Very different figures have been assigned to the temperature of the poles of the electric arc; thus Professor Rosetti, after a long series of experiments, gives + 3,200° to 2,500° Centigrade; Professor Dewar + 6,000° Centigrade; Professor Becquerel + 2,000° Centigrade. Now, taking the lowest of these, and assuming the law of Becquerel to hold good for high temperatures, each

[1] This communication was read and discussed at a Meeting of the Students on the 9th of May, 1884, and has been awarded a Miller Scholarship.

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unit of area of the electrode would emit a light 191,000,000 times as intense as that of a body at 916° Centigrade (melting point of silver). The most simple method of conversion is by chemical action, exemplified in galvanic batteries, the efficiency of which, as will be seen by comparing the energy obtained by the combination of zinc in various cells by Julius Thomsen, with the energy of combination of a given weight of zinc with oxygen, is very high; but the relatively high price of the fuel consumed, and the fact that the heat procurable from a given weight of zinc is only about one-seventh that obtainable from coal, prohibits its use. Many attempts to attain the end more directly have been made (for example, thermo-electric generators, gas, batteries, &c.), but at present not one is in a position to compete with the dynamic method. Now since loss is always consequent upon the conversion of one form of energy into another, it should be the aim of the engineer both to reduce the number of conversions and to diminish each to a minimum, so that the highest possible percentage of the original store of energy may be obtained at the focus of illumination. By loss here is meant energy not expended in the desired direction: of course no actual loss can take place. The conditions of electric lighting may be represented by a simple case of dynamics, for in both the reclaimed energy is due to fall of potential—in the one case electrical, in the other mechanical. Take the simplest example—that of a falling weight—and let the machine in one case be a man, and in the other any dynamic generator of electricity. The man produces a great difference of potential by carrying the weight up, say, a monument; the other generator effects the same by mechanically cutting lines of magnetic force. The fuel for the first machine is provided by fat and muscular tissues, for the second by the potentiated radiant energy of other ages. This difference of potential is in the one case expressed in lbs., in the other in volts. The weight rests at the top of the monument; the flag-stone offers too great a resistance for it to overcome: the circuit of the machine remains open; the cold air offers too great a resistance for it to overcome. Imagine a number of sheets of, say sackcloth, to be suspended horizontally from top to base of the monument; imagine the external circuit of the machine to be composed of a like number of units of length. The weight is cast off the monument, it overcomes the resistance of each stratum of sackcloth, and, forcing its way through, imparts to each a modicum of heat. The circuit is closed, the electromotive force overcomes the resistance of each unit of length, and, forcing a current through, imparts to

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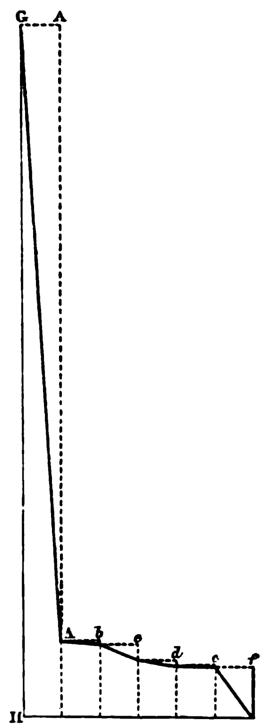
each a modicum of heat. On the arrival of the weight at the base, it has the same potential as the earth; on arrival of the current at the other pole it has the same potential as this latter. In both cases the work done, or heat produced, which is the same thing, will have a relation to the amount of fuel consumed dependent upon the efficiency of each machine. The efficiency of the man depends upon his weight; that of the generator upon dispositions too numerous to mention here. But this heat has been wasted so far as the production of light is concerned, for although a sufficient quantity was present, it was not sufficiently concentrated to produce light. Now reduce the resistance in circuit by diminishing the number of strata of sackcloth, or by lessening the thickness of each. Also reduce the resistance in circuit by diminishing the number of units of length or increasing the sectional area of each; substitute for the lessened resistance of the sackcloth a sheet of iron, and for the diminished resistance of the conductor an arc: the weight again falls, and meeting with scarcely any resistance, except at the plate, most of its momentum is utilized in penetrating the iron and producing a flash of light. The current again flows, and meeting with scarcely any resistance, other than that of the arc, most of its energy is used in producing light. There is yet one thing more—the inverse or counter electromotive force of the arc. This may be represented by the momentum of a stone thrown upwards and meeting the falling weight just as it enters the iron plate. Fig. 1 shows this fall of potential when a steam-engine is employed. The fall is due to the following efficiencies:—Steam-engine, 11 per cent.; gearing, 95 per cent.; dynamo-electric generator, 80 per cent.; cables, 93 per cent.; and carbons, 94·4 per cent. The ordinate G H represents the potential energy of coal (that is, the energy with which the carbon wishes to unite with the oxygen of the air). In this case let G H represent 1 lb. of coal = 800·0 cent.-units of heat × 1,390

FIG. 1.



foot-lbs. = 333·6 HP. per minute = 5·56 HP. per hour. Under the conditions shown the energy expended in the arc will be 0·4 HP., which will yield a light (in an arc of great power) equal to about 800 standard candles for one hour. If the whole energy had been transmitted to the generator, a light equivalent to about 7,420 candles would have been produced, whilst if the whole fall of potential had taken place in the arc, a light of the intensity of about 11,120 candles for an hour would have been the result.

The Arc.—Of the several methods of converting electrical energy into light, the two most frequently employed are known respectively as the arc and incandescence methods. The light in the former method, that of Sir Humphrey Davy (1810), is produced by causing the current to traverse a small space between carbon points. This opposing great resistance to the passage of the current causes intense heating of the electrodes, and light is the result, due, first to the incandescence of the solid carbon points, and secondly, to the stream of incandescent carbon particles which forms the arc. The light emitted by the former, which is by far the more intense, is similar to that of the sun in composition, whilst that of the latter is extremely rich in the more refrangible rays, and gives to electric light its characteristic tint. On account of this disintegration and oxidation of the carbon electrodes, it is necessary, in order to produce a continuous light, to provide means for automatically feeding the electrodes, and this is generally effected by a piece of mechanism known as a regulator, or arc-lamp.

Regulation of the Arc.—The following are among the essentials of a good regulator or lamp:—Its working-parts should be as few as possible, and easily accessible for cleaning, &c. It should be so simple that repairs to it can be entrusted to workmen of ordinary intelligence. The works should be well covered, and placed above the arc, so as to be proof against the entry of ash and small particles of carbon. It should be capable of being so adjusted as to allow a definite strength of current to pass if one lamp only is to be placed in circuit; or to maintain a definite resistance of arc, in other words to preserve a constant difference of potentials between the two electrodes, if several lamps are to be worked in series. If the lamp does not fulfil this requirement, more current will pass, more motive power will be absorbed, heating of the machine will ensue, and the whole system will be subjected to a greater strain than that for

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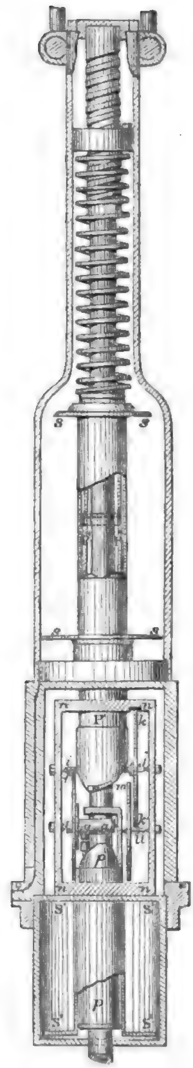
which it was originally intended. The moment of inertia of the controlling parts should be small, so that it may promptly respond to any variation in the required conditions. It should be capable of imparting a delicate feed to the carbons at short intervals of time. Its mechanism when not in the act of feeding, should be locked, so that no swinging, jarring, or bodily movement of the lamp will cause it to feed with a normal arc. The lamp should be provided with both a coarse and a fine adjustment, in order that it may answer immediately to any sudden lengthening of the arc (such as that, for example, which frequently occurs from the falling off of a portion of the electrodes) without the necessity of waiting for a prolonged action of the fine adjustment.

Fig. 2.



The number of forms of mechanism which have been devised for the purpose of effecting the necessary feed of the carbons is very great, and it is extremely interesting to trace their development towards perfection. The Author will, however, explain only that apparatus appertaining to electric lighting, with which he is connected. Diagrams showing the disposition of the parts of the lamps and the method of connection are given in Figs. 2, 3, 4, 5, and 6.

In order to obtain delicacy in the feed, most lamps hitherto have been provided with long trains of wheel-work, with the object of lessening as much as possible the work done by the governing device, and of reducing a comparatively coarse feed of the governing-device to a very fine one of the carbons themselves. The feed is generally governed by the movement of heavy armatures or solenoid cores. Two great disadvantages in this method of governing are: first, that the moment of inertia of both the train and the armatures is too great to allow the system to respond to very slight deviations from the required conditions; and secondly, that as the force acting between the magnet and its armature varies

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as the square of the distance through which it acts, the power of the governing-device varies greatly with its position. Consequently, when the governing-device is actuated by any deviation from the required conditions of the system, it can never cease to act exactly when the required condition has been regained, but must continue to act until a deviation has been produced in the opposite direction. For the governing-device the Author employs a very light and delicately suspended or balanced electro-magnet, or solenoid, working under the influence of controlling electro-magnets or solenoids. In Figs. 2, 3, 4, 5, and 6, *a*, *b*, *c*, represent the delicately balanced electro-magnet, and to which for brevity the Author has given the name "reaction or reciprocal armature." The poles which control the action of this reciprocal armature are formed by the prolongation of the plungers *p*, *p*, and P′, P′, of the solenoids.

The reciprocal armature has not a continuous paramagnetic core, but consists of two cores separated by diamagnetic material. The core *b*, *c*, has wound upon it a wire forming a continuation of the wire upon the solenoid S′, S′, S′, S′, which is so connected as to form a shunt or derived circuit to the arc; that is, the current flowing in the circuit thus formed does not pass through the arc. The arrangement is very similar to the by-pass upon an ordinary gas-main. The wire coiled upon *a*, *b*, virtually forms part of the main circuit, namely, the circuit through both the arc and the by-pass, although for constructional reasons it is made to form a derived circuit to the solenoid *s*, *s*, *s*, *s*, in order that a much finer wire may be employed. Attached to the diamagnetic portion of the armature is the brake-spring *e*, *e*, *e*. The plungers *p*, *p*, and P′, P′, project from the top and bottom of the gearing frame, and play within the solenoids *s*, *s*, *s*, *s*, S′, S′, S′, S′. Consequent upon the strength and sensibility of the reciprocal armature the Author has been enabled to employ a very short train; it consists of the first wheel *f*, *f*, connected to the pinion *g*, *g*, which gears with the rack through the intervention of a rachet wheel, in order that the rack may be raised without the necessity of revolving the train backwards. This first wheel gears with the pinion *i*, keyed to the arbor *j*, upon which is mounted the wheel *k*, *k*, gearing with the small pinion *l*, *l*. This latter carries the aluminium brake-wheel *m*, *m*, the total weight of which together with the pinion is about $\frac{1}{10}$ oz.

The action of the lamp is as follows:—when no current is flowing the gearing frame *n*, *n*, *n*, *n*, rests nearly upon the bottom of the framing of the lamp, in which position the carbons are in

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contact. Upon a current passing through the lamp the plunger

Fig. 3.

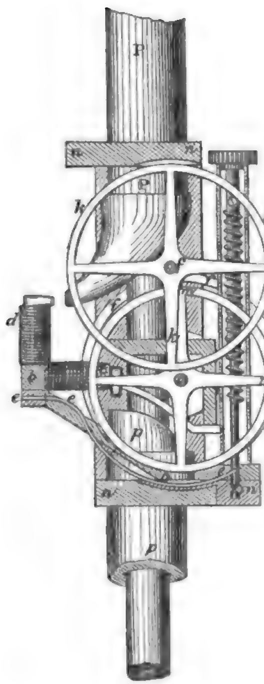


Fig. 4.

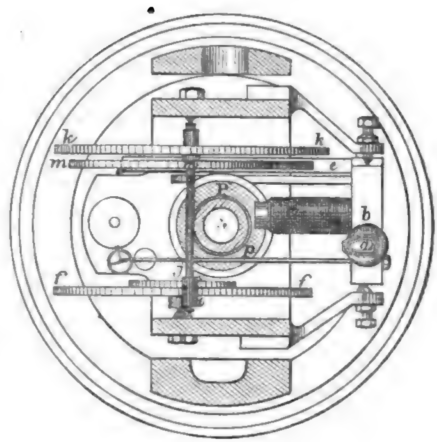


Fig. 5.

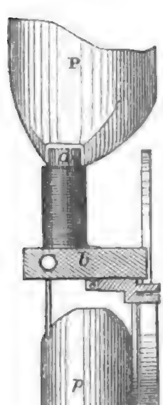
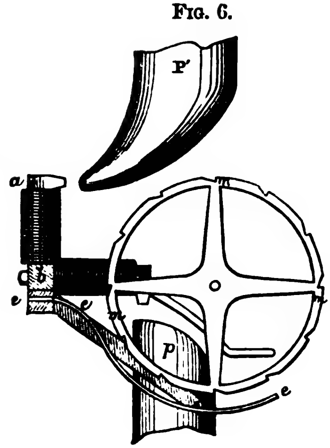


Fig. 6.



P, P, is drawn up into the solenoid *s, s, s, s,* and by this motion

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the arc is formed; the current now flows through *s*, *s*, *s*, *s*, *a*, *b*, and the arc, and by the other route through S′, S′, S′, S′, and *c*, *d*. The directions of winding are such that repulsion takes place at *a*, and attraction at *c*, and these may be made to just balance each other with a given difference of potentials between the electrodes. In order, however, that the lamp may be adjusted to maintain any length of arc at will, the attraction at *c* is made to be slightly in excess of the repulsion at *a*, in order that a certain amount of twist may be imparted to the system, the amount of which, however, may be regulated by the tension of an adjusting spring.

By this means the Author has been enabled to employ a governing-device, whose power and sensibility are independent of its position in relation to the controlling poles, and thus the objections above referred to have been eliminated, the motion of the feed-mechanism being arrested immediately the required conditions are fulfilled. In order to reduce to a minimum the electrical energy necessary to perform the mechanical operations of the lamp, the solenoid *s*, *s*, *s*, *s*, is assisted in its work by a suspension spring, or by being partially balanced, and this increases the sensibility of the lamp, since it causes it to respond immediately to any sudden lengthening of the arc by the bodily movement of the gearing-frame and train.

It is obvious, in order to make the efficiency of an arc-lamp as high as possible, that care should be taken, first, that the resistance introduced into the main circuit be as small as possible, and secondly, that the smallest possible amount of energy be allowed to flow through the shunt or by-pass circuit. The resistance of this latter then should be as great as possible, and by the employment of the reciprocal armature, the Author has been able to raise this resistance to 2,000 ohms. On account of the resistance of the shunt, or by-pass being so great, it is almost impossible to burn it, especially if the generating plant be provided with suitable regulating appliances. The burning of the shunts of differential lamps has hitherto been a source of some trouble.

A peculiarity of this lamp consists in the fact that it will continue to feed even though the shunt be burned. In order that it may do this, a little lever is generally attached to the cross-bar *b*, *b* (Figs. 2, 3, 4, and 5) of the reciprocal armature, and projects in the opposite direction to the brake-spring *e*, *e*, *e*. Projecting from the rigid frame of the lamp is a stop, so placed in relation to this lever, that when the gearing frame *n*, *n*, *n*, *n* descends, it engages with the lever and thus removes the brake. The action of the lamp after the burning of the shunt is easily seen. The

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gearing-frame, when a normal strength of current is flowing, is held up against the top of the rigid frame. As, however, the length of the arc becomes greater, and its resistance in consequence increases, the gearing-frame slowly descends, and after a time the lever engages with the stop, and the brake being thereby removed, the mechanism feeds, but ceases to do so as the strength of current increases, and the gearing frame gradually rises. The rack instead of being solid is formed of a drawn brass tube, and the arbors and the fulcrum of the reciprocal armature instead of being supported in bearings are carried upon hardened steel points. The employment of the latter greatly increases the life of the motion.

Before considering the other apparatus employed in electric lighting, it will be interesting to glance at the relation which lighting by the electric arc bears to other methods of illumination. As regards—

Heating.—The thermal effects of the electric arc, as of all other sources of light, are due far more to the rays of longer than to those of shorter wave-length, but with the electric light it is very pronounced. The ratio of the invisible to the visible radiant energy of the sun is about as 2 to 1, whilst in the electric arc it is nearly as 8 to 1 (Tyndall). The area of the incandescent body in the electric arc is so diminutive when compared with the area necessary to produce an equal amount of light from gas, oil, or other source, that although the temperature of the former is so much more elevated than that of the latter, yet the rise in the temperature of the surrounding air, due to convection, is infinitesimal when compared with that due to gas and other sources of illumination producing a light of equal power. In order to illustrate this, the electric arc may be viewed as an ordinary domestic fire, from which nearly the whole of the air deriving its heat by convection passes away by the chimney, since in the arc the heating by convection may be nearly neglected. The remaining energy is spent in communicating oscillatory movements to the luminiferous ether. The waves thus produced do not heat the air in their passage through it, but are converted into heat only when they traverse an absorbent medium, or impinge upon the walls, ceiling, floor, &c., of the apartment, and it is from these latter that the air derives its increase of temperature. The heating effect, then, of the electric light in an open space may be said to be nil. In a confined space, a rise in the temperature of the air will take place proportional to the energy expended in the arc. Since, however, the amount of light produced per unit of heat so expended is so much

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greater than by other means, the air will receive a much smaller increment of heat by this than by other methods of illumination. For the purpose of comparison imagine a chamber, say 50 feet square by 20 feet high, from which no loss of heat can take place, to be illuminated for ten hours by a light equal to that given by 4,000 standard candles, the light being produced respectively by the electric arc, by incandescence electric lamps, by gas, and by candles. At the end of the ten hours the temperature of the atmosphere of the chamber would be raised :—

	Centigrade. °	Fahrenheit. °
By the Electric Arc	0·706	1·27
By Incandescence Electric Lamps. . .	7·0	12·6
By Gas	78·4	141·0
By Candles	190·0	342·0

In other words if, at the commencement of the ten hours, the atmosphere of the chamber had been at the ordinary temperature (16° Centigrade, or 60°·8 Fahrenheit), then at the expiration of the ten hours it would have been raised :—

	Centigrade. °		Fahrenheit. °		Centigrade. °		Fahrenheit. °
By the Electric Arc from . . .	16	or	60·9	to	16·7	or	62·1
By Incandescence Electric Lamps .	16	,,	60·9	,,	23	,,	72·9
By Gas	16	,,	60·9	,,	98·4	,,	201·8
By Candles	16	,,	60·9	,,	206	,,	402·8

Secondly, as regards the products of combustion :—

Vitiation of the Atmosphere, due to various methods of Illumination.—Compared with other methods of illumination the products of combustion from the electric arc are very small. In order to obtain a comparative review of the amount of defedation consequent upon the employment of the more important illuminants, reference will be made to the before-mentioned 4,000 candle-power and to the hypothetical chamber. The amount of carbon consumed during the ten hours would be about 1,750 grains, and this, combining with the oxygen of the atmosphere, would yield 6,413 grains of carbonic anhydride (CO_2) = 7·4 cubic feet (barometer 30 inches). There would also be a small amount of nitrous acid as nitrites, probably about 771·5 grains of nitrous anhydride.

The amount of these products will depend upon the position of the arc, whether it is confined or if the air is permitted to play freely around the poles, also whether the carbons be placed horizontally or vertically; if placed horizontally the amount of the products will be much greater. There will also be a slight trace of sulphur, as the Author has found this in all the well-known

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carbons; it will probably be given off as sulphurous anhydride (SO_2). In order to facilitate comparison, the Author has drawn up the following Table, showing the carbonic anhydride, etc., produced per hour from an equal amount of light derived from the sources mentioned:—

PRODUCTS of COMBUSTION from VARIOUS ILLUMINANTS.

—	1 CO_2.	2 N_2O_4.	3 S.	4 H_2SO_4.	5 H_2O.	Remarks.
	Grains.	Grains.	Grains.	Grains.	Grains.	
Electric Arc	6,413	8	trace	..	none	Traces of cyanogen.
Gas No. 1 .	852,929 = 122 lbs.	trace	333[1]	1,019	286,848 = 41 lbs.	Ordinary burner. Average gas.
,, No. 2 .	339,889 = 48½ lbs.	trace	125[1]	382	107,568 = 15·31bs.	Siemens burner.
Paraffin oil.	573,040 = 73 lbs.	none	trace	trace	2,683,000 = 383 lbs.	..
Candles No. 1	1,410,860 = 201·5lbs.	none	none	none	5,760,000 = 823 lbs.	Sperm.
,, No. 2	1,141,514 = 163 lbs.	none	none	none	6,336,000 = 905 lbs.	Paraffin.

It will be observed that no absolute value can be given to express the relation between the electric arc and other methods of illumination as regards their effect upon the purity of the atmosphere, since the efficiency of the arc (in respect of illumination) varies with the amount of electrical energy passing between the electrodes; whilst the amount of light obtained from the combustion of a given volume of gas depends upon its quality, upon the burner or manner in which the chemical combination is accomplished, and upon the temperature at which the chemical combination is effected. With regard to oil and candles, doubtless the effect of concentration of heat in varying the proportion of luminous to obscure radiation will hold good in these cases also; for although a given weight of paraffin or stearine can only potentiate a definite amount of energy, there are several forms in which this energy may be taken from it.

Referring again to the hypothetical chamber, it would have

[1] Combines with O to form SO_2, and this, combining with O and H_2O, forms H_2SO_4.

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been necessary, in order to reduce the amount of defedation of the air as regards CO_2 to the standard of that of the air of a manufacturing town, to have changed the whole of the air in the chamber during the ten hours, as given in the second column. The first column showing the relative amounts of CO_2.

	Relative amounts of CO_2.	Times.
For the electric light	1	$3\frac{3}{4}$
" gas (No. 1 in Table) ordinary burner and average gas	133	500
" gas (No. 2 in Table) Siemens burner	53	200
" paraffin oil	80	300
" candles (No. 1 in Table) sperm	220	830
" candles (No. 2 in Table) paraffin	178	670

Actinic power of the Electric Arc.—The spectrum of the electric arc is very long, due to prolongation both at the infra red, and ultra violet ends, but its length varies with the length of arc. The spectrum of the incandescence electric light is similar to that of candles, &c.; but it varies greatly with the temperature to which the filament is raised, the proportion of luminous to obscure rays being in the arc about 1 to 9 (Tyndall 50 groves), in gas 1 to 24, in white hot platinum wire 1 to 23.

The actinic effect of the electric arc depends on three factors, one of which is constant and the other two variable. The constant factor depends on the current, since it varies with the area of the crater; the other variables depend on the kind of carbon employed for the electrodes and upon the length of the arc.

The Author thinks it advisable to point out the conditions which he has found favourable to the development of actinic action on a given surface.

First, a very long arc should be employed.

Secondly, a line normal to the plane of the specimen should form an angle of from 30° to 50° with the axis of the carbons, if these are placed vertically and the axis of one carbon is coincident with the axis of the other. He has found it more convenient, however, in many cases to arrange the carbons as in military and naval lighting, by which the rays of greater refrangibility proceeding directly from the crater are utilized. The observance of these conditions is obviously of great importance, when it is required to obtain the maximum speed from a given arc in the printing of photographic transfers, &c. Upon plotting a number of results it was found that the curve of actinic effect was practically coincident (especially for moderate powers) with that of illuminating power.

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Penetrative power of the Electric Arc.—There appears to be a marked distinction between the quantity and intensity of a light. Just as by increasing the velocity of the armature of a dynamo-electrical machine an increase occurs in the quantity and (to use an obsolete expression) the intensity of the current, so in augmenting the temperature of an incandescent body both the quantity and the intensity of the light increase. An analogy may be drawn from a musical sound, a vibrating string for example. In a musical sound the timbre or character of the sound is dependent upon the character and number of sounds of different and shorter wave-length which are combined with the fundamental sound, whilst the character of a light is dependent upon the character and number of rays of different and shorter wave-length combined with that of the principal wave-length or fundamental light. In the former, by striking the string with varied force and in a different manner the proportion of these sounds of various wave-length to the fundamental wave-length may be altered, and with it the character of the sound produced. So, by increasing the temperature of an incandescent body, the proportion which the rays of various and shorter wave-length bear to the fundamental wave-length is altered, and with it the character of the light. That is to say, while the amplitude of original vibrations is increased, new ones of shorter wave-length are produced, and thus the light changes in character and becomes more intense. But does this increase in intensity signify increase in penetrative power? or rather, is the amplification in the power of penetration due to increased power on the part of the slower vibrations, or to the introduction of the new and more rapid ones? This will depend upon the character of the obscuring medium; for it must be remembered that the more rapid the vibrations, the more refrangible are the rays they produce, and hence it may be that one set of vibrations or character of light may be suitable for traversing a dry obscuring medium, such as smoke, and another series may be more adapted to the permeation of a humid medium, a fog or mist for example.

In a damp obscuring medium, such as fog, the rays of shorter wave-length have the greater penetrative power. One method of observing this is to mount an eminence and look along a straight road lighted by gas- or electric-lamps. It will be observed that each successive light farther from the observer has a more yellow, and in the remote ones a more ruddy, tinge than the preceding ones, and that the farthest light will be of a decided red as compared with the nearest. The great change in colour in the rising

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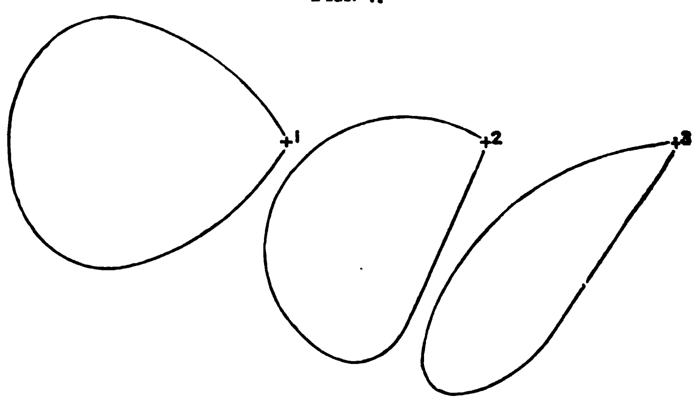
moon on misty evenings may be cited as another example. These facts go to show that the beacon fires employed in olden times were well adapted to fulfil their requirements, and also that for lighthouse illumination and other positions where penetrability is the desideratum, very strong currents producing large masses of heated pole, a short arc, and a small difference of potential between the poles (say 60 volts), should be employed.

Distribution of Light from the Electric Arc.—As in almost every source of illumination, the light produced by the electric arc is not emitted uniformly in all directions, its amount, colour, and distribution depending upon several conditions. The amount depends on the electrical energy in the arc, the length of arc, and

FIGS. 7.



the chemical composition of the electrodes. The colour on the length of arc, the character of current employed, and the composition and density of the carbons. The distribution on the length of arc, the character of the current, and on the carbons themselves. The annexed diagrams (Figs. 7), show the distribution of light from various arcs: 1. when an alternating current is used; 2. an arc of moderate size produced by a uni-directional current; 3. a short arc and small uni-directional current.

For general illumination and industrial purposes the positive electrode is usually placed above the negative, its axis being vertical and forming a prolongation of the axis of the negative; but for special purposes it is sometimes advantageous otherwise to dispose the electrodes. In search lights, for example, the upper carbon is generally placed in the rear of the lower, so as to expose the crater toward the front. For lighting with vertical carbons,

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the Author prefers to employ an upper carbon of about 3 or 4 millimetres greater diameter than the lower. It will be seen from the diagrams that whilst the addition of reflectors to the alternating-

FIG. 8.

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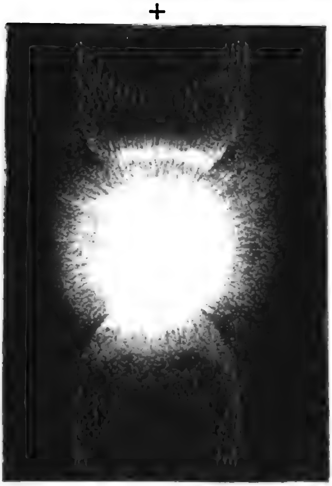

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FIG. 9.

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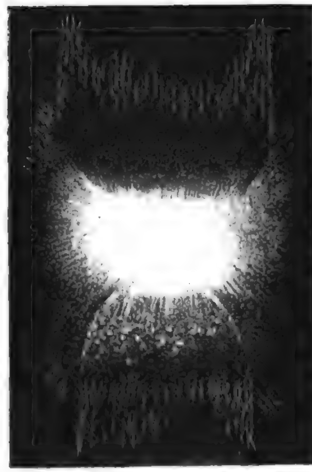

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FIG. 10.

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FIG. 11.

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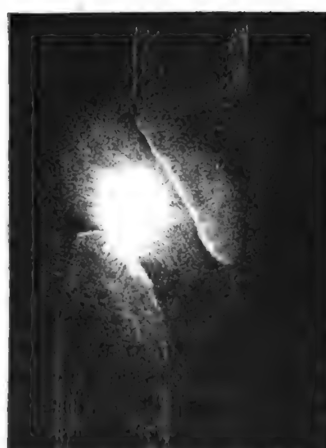

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current lights would have a marked effect on the intensity of illumination of ground area, they would be of little service to moderately short arcs, produced by uni-directional currents; and

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also that the distribution of light from the former is far more uniform than from the latter, especially when very short arcs (such as the Brush) are employed, and the arc is not situated far above the horizontal plane to be illuminated.

With regard to the fluctuations in the intensity of the light emitted by the electric arc, with alternating currents, and with uni-directional currents of feeble strength and great electromotive force, the arc is in incessant vibration and motion around the points in its endeavour to pass by the path of least resistance, and in this they present a marked contrast to the fixity of the light emitted from arcs produced by currents of great strength and of small electromotive force working with a moderate length of arc.

FIG. 12.

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With a long arc or feeble current the colour of the light is less pure, being more violet or purple as a greater amount is derived from the arc proper and less from the incandescent electrodes. In addition to the greater stability of currents of low electromotive force, the light emitted by arcs produced by them is less influenced by any momentary vacillations of the current or movement of the arc; since, with feeble currents, the electrodes become heated only in the immediate vicinity of the points where the arc leaves and enters them, whilst with powerful currents a comparatively large surface of the electrodes becomes incandescent. Figs. 8, 9, 10, 11, and 12 serve to give a general idea of the appearance of the arc, with various dispositions of the electrodes. In each case the same (powerful) current was employed.

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Fig. 8 is that of an arc of moderate length.

Fig. 9 represents an arc of the same power, slightly shorter, and with an upper carbon having a diameter 3 or 4 millimetres in excess of the lower one.

In Fig. 10 the front or crater side of an arc having the upper (positive) carbon about half its diameter is in the rear of the lower as hereinafter explained.

In Fig. 11 the same disposition is seen from the side (= 90° from the preceding view).

Fig. 12 is that of an arc set very short.

It will be observed (more especially in Fig. 12), how very much higher in temperature the positive carbon is than the negative.

For lighthouse purposes the arrangement of carbons already mentioned, namely, when the upper carbon is placed about half its diameter in the rear of the lower, so that its front edge nearly corresponds to a vertical line drawn through the axis of the lower, is generally employed. It is not of paramount importance that a lighthouse-lamp should emit its maximum light in a perfectly horizontal plane, since the optical apparatus in which the lamp is situated has the effect of reducing to parallelism all the rays emitted; indeed, by placing the positive carbon below, a simplification of the apparatus is effected, for by thus giving the rays an upward direction, and throwing the chief work upon the upper catadioptric zones, a diminution in the number of lower catadioptric prisms is permissible. For military and naval purposes, however, it is necessary to have the maximum light in a horizontal direction, and for this purpose the carbons (arranged as previously described) are inclined at an angle of 20° with the vertical. In the ordinary holophotal projectors the crater is turned in the direction in which it is desired to project the light, the divergent rays being rendered parallel by the prismatic zones of the dioptric lens; whilst, in what is known as the Mangin projector, the crater is turned in the opposite direction, and faces a concave mirror, the peculiarity of which consists in the fact that the outer and inner surfaces, namely the silvered and unsilvered surfaces, have different degrees of concavity, the ratio of the radii being so adjusted that the inner (transparent) surface corrects the spherical aberration of the outer (silvered) one.

For ordinary industrial purposes, it is generally required to illuminate uniformly a horizontal plane at a certain distance below the arc. Reference to the diagrams (Figs. 8 to 12) will show that this is rather imperfectly accomplished by the unaided arc, since the lower or negative electrode casts a circular shadow on

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the horizontal plane, the area of such shadow increasing with the square of the height of the arc, which should always be great to obtain economy and uniformity in lighting. In order to obviate this difficulty, the Author suggests the method of utilizing the rays proceeding in upward and horizontal directions, and which are useless for the illumination of ground area, by surrounding the arc in and above its horizontal plane by an annular totally reflecting prism, having angles such that rays originally having an upward and horizontal direction are turned downwards and made to illuminate the otherwise less intensely illuminated portion beforementioned. The reflected rays may be made to take any required direction by curving the totally reflecting side of the prism. In lamps for industrial purposes, in which it is required to attain this end in an inexpensive manner, the annular prisms might be constructed of sheets of glass, filling the interior with a liquid, say distilled water.

In many instances, however, it is of more importance to diffuse the light uniformly in all directions and in such manner as to obviate the production of shadows.

Diffusion of the Light of the Electric Arc.—On account of the very small space occupied by the electric arc, and of its great illuminating power, the resulting shadows are extremely dense and well defined; and it is therefore generally found necessary to employ devices for diffusing the light.

The usual method is to place the arc within a globe of ground, frosted, opal, or alabastine glass. The globes should be of large dimensions; for, as every part of the diffusing medium becomes self-luminous and may be considered to be giving out light in all directions, it is clear that shadows, when an arc is surrounded by a diffusing globe of large dimensions, will be much less clearly defined at their edges, and will be fainter (if the object be small and moderately near the light) than if the light be naked or one provided with but a small globe.

However, the loss of light by absorption in various diffusing media has not been thoroughly investigated, and the results which have been obtained are very discordant. In measuring directly by first taking a reading of the naked light and then interposing the substance whose absorption is required to be ascertained, and afterwards taking another reading, the result is as much an indication of the dispersive and reflective effect of that particular substance as of the light absorbed, since the intensity of the light which originally fell upon the screen of the photometer is, by the use of the diffusing medium, diminished by being caused to occupy a larger area, and also by many of

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the waves being turned back by reflection. The loss will, therefore, vary with—

1st. The distance of the specimen from the screen of the photometer.

2nd. The size of the specimen or that of the aperture through which the light is admitted to it.

3rd. Its reflective effect.

The Author proved the accuracy of the first assumption by taking separate sets of readings, one set at a great and others at smaller distances from the light. The second assumption was too obvious to need verification. Figs. 13 and 14 will show this.

FIG. 13.

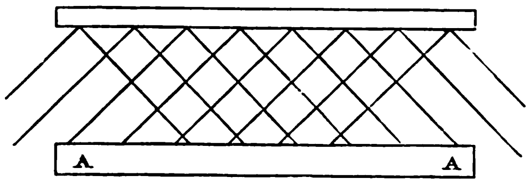
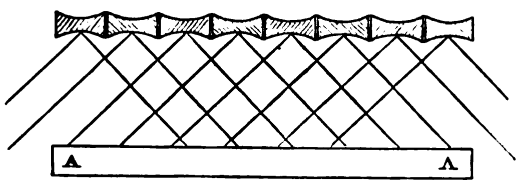


FIG. 14.



Imagine the specimen to be composed of an infinite number of bi-concave lenses, then it is evident that the amount of light falling on the given area A will vary with the first and second conditions.

Another method of diffusing electric light, which is very effective, but which is generally considered to entail great loss of light, is that in which the arc is concealed from view, the resulting light being due entirely to reflection. Doubtless a large amount of light is lost by this method, but it must be remembered that a smaller amount of well-diffused light is often quite as efficacious as a much larger amount wanting in uniformity of distribution. This is especially the case in manufactories in which delicate operations are carried on, or where machinery in motion casts moving shadows. For physiological reasons, also, this is true; for if the eye be not called upon to respond to great variations in intensity of the light, a smaller amount will suffice. If

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the direct rays from a powerful source of light fall upon the retina, the workman or workwoman will not recover his or her maximum sensibility of vision for a perceptible time after. The Author has made some rough experiments in this direction, and has found that the period before normal sensibility is regained is longer the more intense the light, and that this period is very considerable. He also found that it varied to a great extent with the colour of the light.

Relative Efficiencies.—The comparison of the efficiencies of the different modes of illumination is an interesting and instructive consideration, but it is one beset with considerable difficulty, as scarcely any complete set of efficiencies has been taken. The greatest difficulty, and probable point of inaccuracy, is in the photometric measurements, as the readings of the instruments used for measuring the candle-power of an illuminant depend greatly upon the difference in colour of the various sources of illumination; again, in no illuminant is the illuminating power the same in every direction. To compare the electric arc and a gas-flame, for example, it must be borne in mind that the distribution of light around the source is not uniform, and that the gas-flame occupies a perceptible space; obviously, then, some different arrangement is necessary for measuring the power of each light. As a way of effecting a comparison it has been suggested to take a number of readings at different angles, and to consider the average as the candle-power of the light. This meets the difficulty to a certain extent, and is the method upon which the Author has based his calculations. The commercial efficiency may, however, be very different. By commercial efficiency is meant the amount of light obtained in the place where it is required. Thus, suppose A and B to give equal lights (average of all directions), and it is wished to have the greatest light at an angle of 45°, then should A give more than its average and B less than its average, A has greater efficiency for this particular place. There may even be a light which has a greater average intensity giving a less degree of illumination in one direction than what another emits from sources of less average intensity.

Other difficulties are the different illuminating power of various gases, the different efficiencies due to the methods and temperatures at which they are burnt, and the different efficiencies of arcs of various powers.

The following Table may be taken as a fair comparison of the efficiencies under these circumstances. The Table is not intended to be a comparison of the costs but only of the efficiency of trans-

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formation; the cost-efficiency depends not only on the efficiency of transformation but also on the economy of the means of transformation.

TABLE SHOWING CANDLE-POWER PRODUCED PER HOUR by 1 lb. of COAL TRANSFORMED in DIFFERENT WAYS INTO LIGHT.

No.	Method of Transformation.	Gas Produced.	Coal Required per HP. Effective per Hour.	Candles per 5 Cubic Feet per Hour.	Gas per Effective HP. per Hour.	HP. given to Dynamo.	Electrical HP. at Terminals of Lamps.	Candle-Power per Effective HP. at Terminals.	Candle-Power per Hour obtained.	Relative amount of Light from each, taking ordinary Gas-burner as 1.
		C. Ft.			C. Ft.					
1	Coal-gas	4·4	..	12	..	..	..	..	10·6	1·0
2	Coal-gas, gas-engine, dynamo and arc lamp	4·4	..	..	30	0·15	0·11	1,200	126·6	11·9
3	Coal-gas, gas-engine, dynamo and incandescence lamps	4·4	..	..	30	0·15	0·11	200	21·1	2·0
4	Dowson gas, gas-engine, dynamo and arc lamp . .	83·3	..	..	125	0·67	0·48	1,200	576·0	54·3
5	Dowson gas, gas-engine, dynamo and incandescence lamps	83·3	..	..	125	0·67	0·48	200	96·0	9·0
6	Steam-engine, dynamo and arc lamp	..	2½ lbs. to 4 lbs.	..	..	0·40 to 0·25	0·29 to 0·18	1,200	348·0 to 216·0	32·8 to 20·4
7	Steam-engine, dynamo and incandescence lamps	..	2½ lbs. to 4 lbs.	..	..	0·40 to 0·25	0·29 to 0·18	200	58·0 to 36·0	5·5 to 3·4
8	Siemens burner, ordinary gas . .	4·4	..	30	..	..	..	..	27·0	2·5

It should be remembered in reviewing the above Table, that on account of its showing the light produced by 1 lb. of coal, that the by-products resulting from the production of ordinary coal-gas cannot be considered. If it had been a consideration of the cost efficiencies instead of light, the efficiencies of Nos. 1, 2, 3 and 8 would have been much higher, as in this case the value of the by-products might have been taken into account.

Data assumed, efficiency of dynamo 80 per cent.
,, efficiency of cables . 90 ,,
,, good steam-engine . 2½ lbs. of coal per effective HP. per hour.
,, average ,, . 4 ,, ,, ,, ,, ,,

The Electrodes.—When the arc is produced in air (which is always the case when employed for industrial purposes) the

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carbon electrodes are gradually consumed in the ratio of about 1 part of the negative to 2 parts of the positive. This consumption is due to the gradual oxidation of the heated points, and to the complete combustion of the moving particles which are projected chiefly from the positive towards the negative.

Now, since the great efficiency of the electric arc consists in its ability of condensing into an exceedingly small space a large amount of heat, it is advisable to employ as electrodes a carbon of very low thermal conductivity in order to localize the heat as much as possible, so as to increase the light and prevent oxidation at a temperature too low to produce light; at the same time the electrical conductivity should be as high as practicable.

Purity, hardness, and homogeneity are the chief desiderata in a good carbon. Out of seven specimens of carbon of well-known make the Author found the most light to be produced by the one containing the least amount of impurities. The following shows the amount of ash in each:—

	Per Cent.
S	12·45
E C C V	5·35
G *y*	3·72
B	3·50
C C C *d*	2·80
C	2·84
G *n* (original Gaudoin)	1·80

The purest carbon, and that giving the highest efficiency, was the last, which was made by Mr. Gaudoin. The others are at present in the market, and the Author abstains from giving the names. The redness of the ashes affords an approximate indication of the amount of iron contained in each specimen. All attempts to increase the illuminating power of the arc, by the introduction of various materials during the manufacture of the carbons, have failed, as the decomposition of such materials produces gases which, at the high temperature of the arc, become conductors. Several methods of preventing the wasting away of the carbons have been patented. One with which the Author was connected consisted in surrounding the electrodes with a hydro-carbon vapour, which, at the high temperature of the arc, became decomposed, and a very hard carbon was deposited upon the electrode; but it was found that the heated gas increased the conductivity of the arc, and the loss of light was very great. In order to obviate the employment of mechanism, and the necessity of frequently renewing the carbon rods, the Author attempted to substitute for the solid electrodes powdered carbon contained in

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large vessels connected with metallic tubes, furnished with non-conducting nozzles of very refractory material. A current of great electromotive force, however, was required, and the light was of a violet hue. As a means of obviating the necessity of repeatedly renewing the carbons the Author constructed a lamp which made its own electrodes as required. The lamp contained two cylinders provided with plungers which were forced in by a powerful spiral spring, the uncoiling of which gave motion to nut-wheels working on a screwed prolongation of the plungers. It was, however, intended to substitute for this in practice a heavy weight descending within the lamp column. The cylinders were filled with powdered carbon mixed with treacle, and one end of each cylinder was provided with a 13-millimetre hole, which acted as the draw-plate employed in the manufacture of carbons. The direction of the carbon rods was controlled by two guide-tubes pivoted at one of their extremities to the covers of the cylinders. These tubes were inclined to each other at an angle, and motion was imparted to them (in order to regulate the length of arc) by means of a solenoid and plunger, the feed being given by the train of wheels driving the plungers, thereby increasing the length of the electrodes. The action of the lamp was satisfactory, but in this, as in the previous instance, the light was blue, owing probably to insufficient density of the electrodes. Coating the electrodes with a thin layer of metal (generally copper, nickel, or iron) increases their durability.

The importance of purity and density in the carbons cannot be too strongly pointed out. No mechanism however delicate can be devised to produce a steady light if imperfect carbons be employed.

The Paper is accompanied by several diagrams from which the woodcuts in the text have been engraved.

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(*Students' Paper, No. 175.*)

"Light Draught Launch." [1]

By EDWARD WOODROWE COWAN and JAMES FAWCUS, Studs. Inst. C.E.

IN the month of January, 1882, the Baptist Missionary Society invited tenders for the construction of a launch, to assist in carrying out their work on the Upper Congo River in Africa.

The launch was required to fulfil the following conditions:—It was not to exceed 70 feet in length; the draught was not to exceed 2 feet 6 inches, and might with advantage be reduced to 1 foot. It was to afford comfortable cabin accommodation for four people, and to be capable of carrying a load of 4 tons. The boiler was to be designed to consume wood as fuel, it being impracticable to procure coal in that part of Africa. The speed was to be 12 miles per hour. The boat was to be constructed in such manner that it could readily be taken to pieces for shipment after trial; the majority of the parts were not to weigh more than 64 lbs. each; and no part was to exceed 1½ cwt., as they all had to be carried by natives for a considerable distance. The launch, which Messrs. Thornycroft and Co. designed, and afterwards constructed, fulfilled these conditions efficiently.

Of the tenders received, in Messrs. Thornycroft's design alone was screw-propulsion adopted, the shallow draught seeming to have precluded its use in the case of other constructors.

Fig. 1 illustrates the launch and its fittings. The total length is 70 feet, beam 10 feet 6 inches at the water line, and greatest draught not quite 12 inches, being more than 1 foot 6 inches less than that required. The total displacement when loaded is 9·82 tons.

The hull is constructed of Bessemer steel plates, attached with iron rivets to forty-six angle-iron frames, and divided into water-tight compartments by three bulkheads and three half-bulkheads; the thickness of the plates composing the hull varies from 20 to 15 Birmingham wire gauge; they are all galvanized.

The hull, Fig. 1, is nearly flat-bottomed in order to reduce the

[1] This communication was read and discussed at a meeting of the Students on the 15th of January, 1884, and has been awarded a Miller prize.

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draught. The wetted surface is 61·3 square feet per ton of displacement, which is very large, and correspondingly affects the displacement-coefficient. This is shown for different speeds by a curve on Fig. 9. It will be noticed that its highest displacement-coefficient, which is at about 280 revolutions per minute, just reached 100, a high coefficient considering the size of the boat and the form of the hull. The launch is propelled by twin screws revolving outwards, and situated in channels formed in the after-part of the hull. The arrangements for steering consist of an ordinary rudder, with a normal immersion of 12 inches, but which, when the depth of the water is sufficient, can by suitable tackle be further lowered, giving an increased immersion of 6 inches; this however was not found necessary.

The tiller is connected to a wheel forward of the boiler by chains and galvanized-iron rods, running through guides in the sockets of the stanchions. These stanchions, twenty-six in number, support an awning of mahogany, covering the boat from stem to stern. From this awning a galvanized-iron wire netting can be suspended, for a protection from the attacks of the natives. There are two cabins, accommodating four people, one forward and one aft; a stove is fitted in the forward end of the after cabin for cooking purposes. There is also a lavatory on deck. Four rowlocks are provided in case it should be necessary to use oars.

The mode of propulsion is a special feature, the design of the screws being the result of a series of experiments made by Mr. Thornycroft. These experiments have been fully described by him in a Paper read at the Institution of Naval Architects.[1] One of the propellers is illustrated in Fig. 2. Its diameter is 16 inches, and it has two blades of a long increasing pitch, in order that the speed of the engines may be moderate. The pitch of the forward edge of the blade is 37·5 inches, of the after edge 154·5 inches. The mean pitch multiplied by the revolutions does not give the correct velocity of the screw with regard to the water, on account of the great increase of pitch affecting the water in a different manner to the true screw. The blades are of gun-metal cast upon a conical boss, the object of this form of boss being to contract the stream of water running through the casing which contains the propeller, giving it a greater velocity corresponding with the increasing pitch of the blades. This stream of water has a certain amount of circular motion imparted to it by the blades, which in an ordinary propeller represents so much work

[1] Transactions, 1883, vol. xxiv., p. 42.

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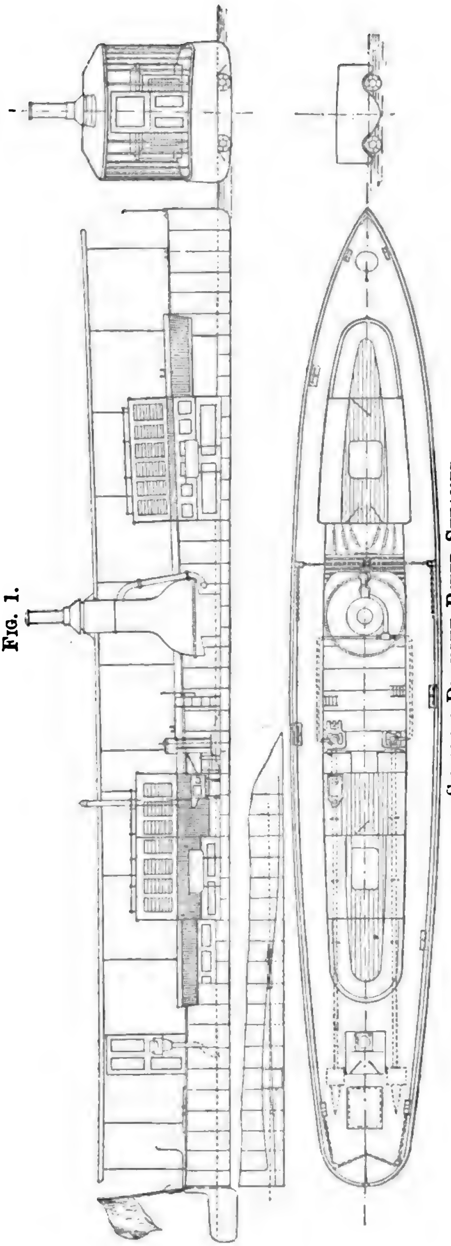
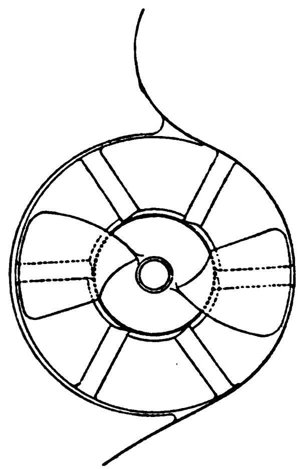


Fig. 1.

Shallow Draught River Steamer.



End View.

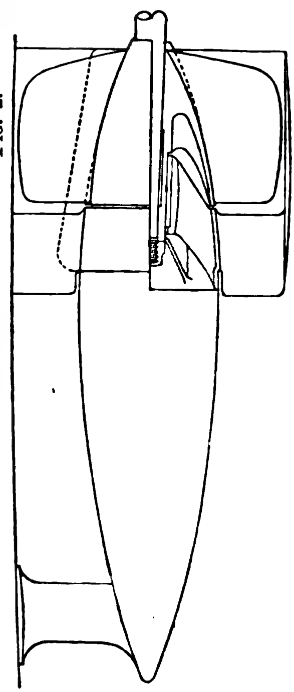


Fig. 2.

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lost; but, in the guide-blade propeller this work is converted into useful thrust by guide-blades, cast radially within the gun-metal casing before referred to. These blades are so curved as to guide the stream of water leaving the propeller into a direct line astern. A cigar-shaped body made of copper, which continues the lines of the boss, is fixed abaft the propeller, its use being to allow the divided stream to unite gradually.

As the propeller is 16 inches in diameter, and the draught of the boat only 12 inches, had it been placed in the ordinary position at the stern of the boat it would have risen 4 inches above the water-line; it was, therefore, necessary to have recourse to a device to give it a full immersion. This is effected by placing it in the channel or cavity, a side-view of which is shown in Fig. 1; in this position the propeller rises 6 inches above the water-line.

The action is as follows:—The propeller on being started exhausts the air in the forward end of the cavity; the water then rises to fill the void, and the propeller is thus able to work fully immersed; at first sight it would appear that work is wasted in so raising the water, but on consideration it will be seen that this is not the case, the action being like that of a siphon, the water raised in the forward part of the cavity being balanced by the fall in the after part. The only disadvantage in this arrangement is, that the water in the cavity becomes, as it were, part of the boat, adding to its weight and consequent displacement; this disadvantage, however, is not appreciable when the efficiency gained by the use of the propeller of larger diameter is taken into consideration.

Had an ordinary screw-propeller been used, its diameter would have been 2 feet 3 inches instead of 16 inches; thus a reduction in diameter of nearly 60 per cent. has been obtained by using the guide-blade propeller.

Such a propeller is of little use for going astern, the boat being almost unable to make way against the tide; but when going ahead it can be stopped in about two of its own lengths by reversing the engines.

The efficiency of the propeller running at 460 revolutions is 0·56, rather lower then it would have been had the diameter been a few inches greater. The slip at full speed is 44·1 per cent. Doors are fitted in the bottom of the boat over each propeller, to enable them to be cleared should they become clogged with weeds; this operation can be performed on one propeller without stopping the boat, as the other can be kept running.

Fig. 3 illustrates a section through the cylinder of one of the

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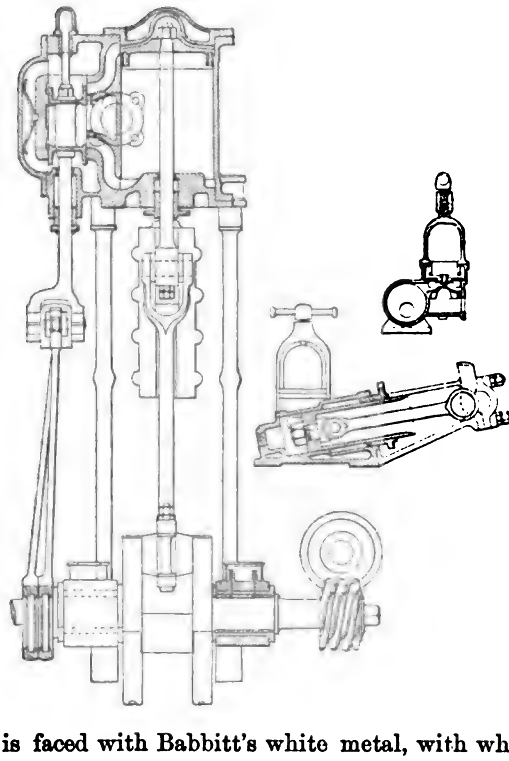
engines; they are single non-condensing, and exhaust into the funnel in the usual way with a view to increasing the furnace draught. The diameter of the cylinder is 6¼ inches, length of stroke 8 inches, and revolutions about 480 per minute, when running full speed. The indicated HP. at full speed is about 60. The thrust of the propeller is taken upon the brass of the after-main bearing;

Fig. 3.



this brass is faced with Babbitt's white metal, with which all the principal bearings of the engine are either lined or bushed. The piston-rings are of Perkins' metal. Two feed-pumps and a bilge-pump, fitted to the port-engine, are driven by a worm keyed on to the forward end of the crank-shaft. The diameter of the plungers of these pumps is 2¾ inches, and the length of stroke 2⅜ inches. The ratio of the strokes of the engine to those of the pump is as 5 to 1.

The weight of the engines per indicated HP. is about 36·7 lbs. The work performed might have been done by lighter engines running at a higher speed, but, as they are to be in charge of

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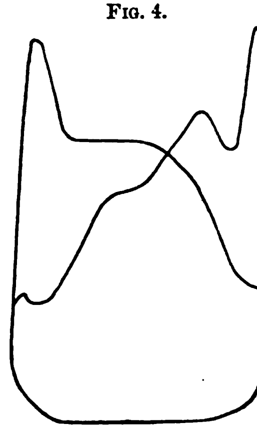
inexperienced engineers, it was considered advisable that the revolutions should be moderate.

A HP. diagram, Fig. 4, needs little remark; the undulations in the steam-line are caused by the momentum of the moving parts of the indicator; the cut-off, which is not very marked in the diagram, is at $\frac{5}{7}$-stroke. A curve on diagram 9 shows the indicated HP. for different engine-speeds. Another curve represents the indicated HP. when the engines were linked up. It will be noted that the power required to run the engines at a given speed when linked up was greater than that required when the steam was throttled. A possible explanation of this may be found in the fact that the friction of the moving parts of the engine is greater when working with a higher pressure with an early cut-off than with a lower pressure cut-off later, and also that the turning moment is less equable in the former case than in the latter.

Fig. 4.



Port Engine.

HP.	27·2
Revolutions per minute	450
Spring	40

To construct a boiler to supply steam for 60 HP. engines, in such a manner that it could readily be taken to pieces, and that no part should weigh more than 1½ cwt., was a problem which involved many difficulties; any boilers in use at the time were out of the question, as they did not fulfil this requirement. The boiler illustrated in Figs. 5, 6, 7, and 8, is that which Mr. Thornycroft designed for the purpose. This boiler is called Thornycroft's patent steam-generator.

A tubular ring encircles the furnace, which has a grate-surface of 7 square feet; from this ring spring fifty-two solid drawn steel tubes 14 feet in length, and 1 inch in outside diameter; these tubes are coiled so as to form a double dome-shaped roof to the furnace. The tubes then rise vertically, until they join the upper end of the separator (Fig. 5); the joints being made at each end of these tubes by screwed glànds with copper washers for packing.

The lower end of the separator is connected to the tubular rings before referred to by means of a pipe returning outside the boiler, the coils being encased in a double shell made of thin Bessemer steel plates.

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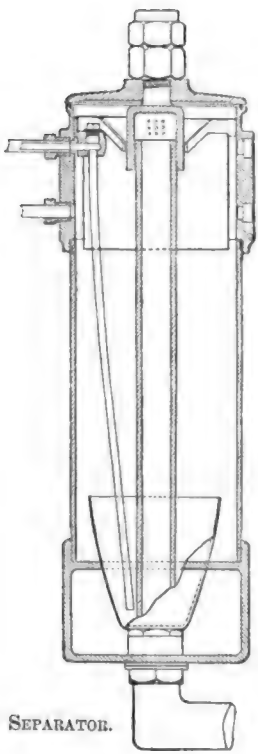
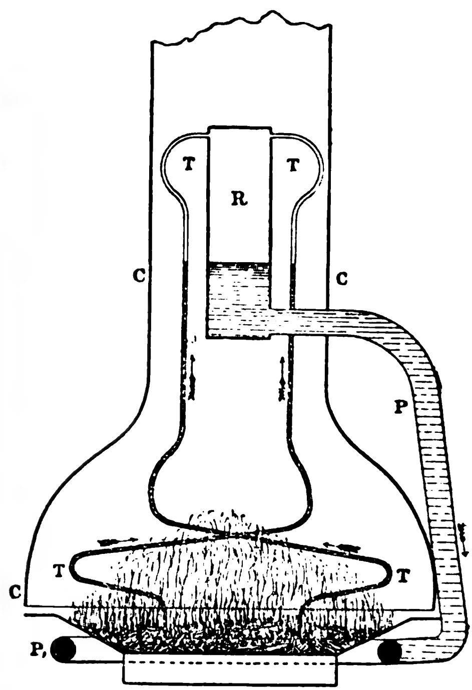
In Fig. 6 is shown this steam-generator reduced to its simplest form for the purpose of illustrating its action. P^1 is the tubular ring at the base; P, the pipe joining the separator, R, to the tubular ring; TT are the steel tubes which form the coils; C is the casing. When starting, the water being at the level shown, the heat from the furnace impinges upon the tubes T T, and rapidly generates steam; the mixture of steam and water

FIG. 5.



SEPARATOR.

FIG. 6.



thus produced in the tubes being lighter than the water in the pipe P, rises and overflows into the upper end of the separator R; the water in the lower end, which was protected from the heat of the furnace by lagging the outside of the lower end with asbestos, falls through the pipe P (which being outside the casing, was not exposed to the heat of the fire) into the tubular ring, and so to the tubes, thus a vigorous circulation is kept up.

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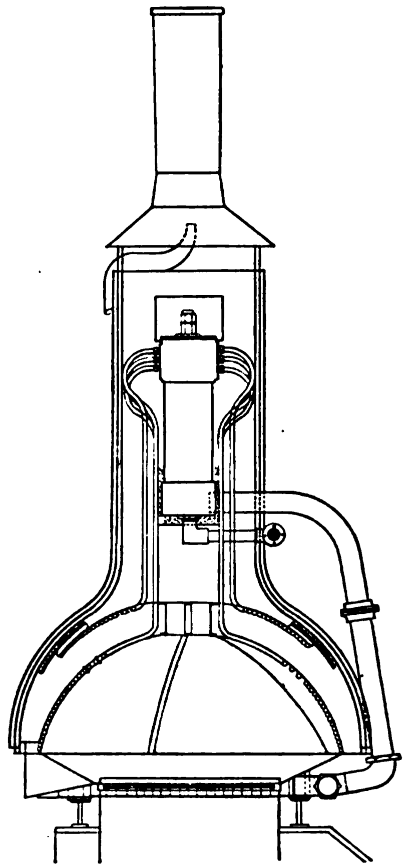
Referring now to Fig 7, the heat from the furnace enters the space enclosed by the first coil of tubes, passes through an opening in the centre of this coil, and descending, raises the temperature of the water in the second coil, and passing between this coil and the outer one (made of copper conveying the feed-

Fig. 7.



water), it rises, surrounding the separator, to the funnel. The mixture of steam and water upon entering the upper end of the separator, strikes a cylindrical gunmetal screen, upon which are cast ribs; these ribs are set so as to give a circular motion to the water, which has the effect of separating it from the steam, the centrifugal force causing the water to cling to the sides and

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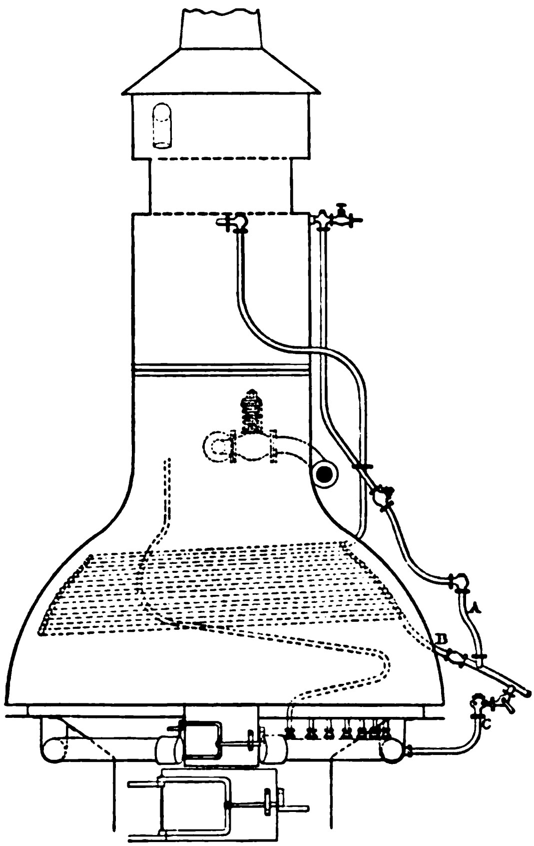
so fall to the bottom; the steam rises within the curtain, and escapes through holes in the top of the steam-pipe running down the centre of the separator. Dry steam is thus obtained.

The copper vessel at the bottom is for the purpose of collecting any sand or other dirt which may be carried into the separator; this dirt can be blown out through a pipe passing out of the top.

Fig. 8.

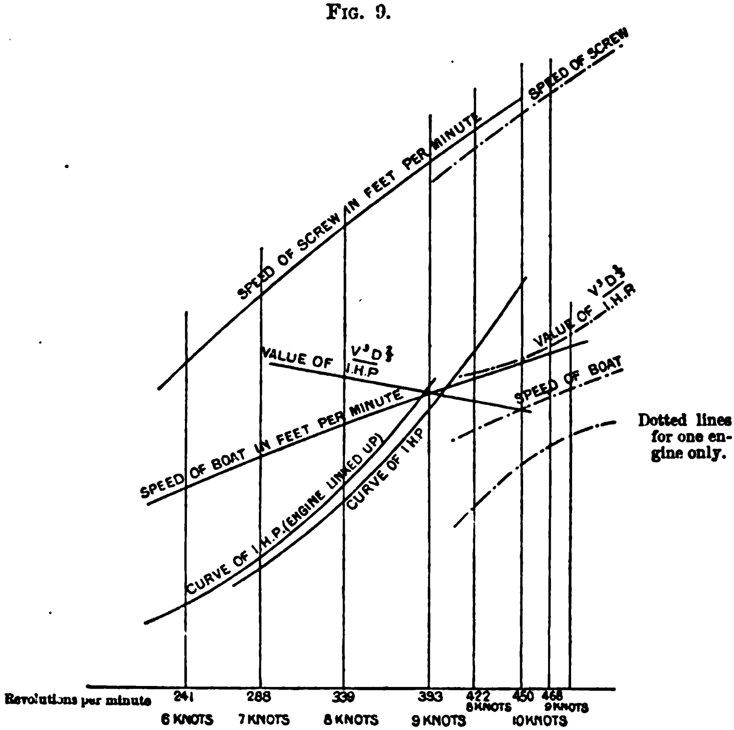


The feed arrangements are shown in Fig. 8; the water which is supplied by either the feed-pumps on the port-engine, a Tangye's special donkey-pump, or a hand feed-pump, passes through the pipe marked B in the diagram into the outer copper coil before mentioned, and enters the top of the separator. By opening the cock in the pipe C, this coil can be made into a

generating coil when the feed-pumps are not working, preventing the pipe from being burnt; but should this pipe by negligence or accident be burnt, the feed-water can be pumped directly into the separator by opening the cock in the pipe A and shutting that in the pipe B.

This boiler has many advantages, among them portability and lightness; its weight per indicated HP. being 49 lbs.; it is a safe

Fig. 9.



Speed scale $\frac{1}{8}$ inch $= 100$ feet.
Scale for I.HP. $\frac{1}{32}$ inch $= 10$ I.HP.
Scale for coefficient $\frac{1}{8}$ inch $= 10$.

one, and this is of great importance, as it is to be in charge of men inexperienced in the use of steam-machinery. One of the tubes of which the coils are composed, was tested to 5,000 lbs. per square inch water-pressure, without rupture. Should one of the pipes get burnt, it can easily be replaced by a spare one, whereas, in a Herreshoff boiler this cannot be done, as the pipe forming the coils is continuous.

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Another advantage attained is the rapidity with which steam can be got up. The following experiments were made for the purpose of ascertaining this point: the gauge started in seven minutes after the fires were lit; pressure of steam, 5 lbs. in eight and a half minutes; 25 lbs. in eleven minutes; 70 lbs. in thirteen minutes. The engines were then started, and a steam-pressure of 90 lbs. was registered in fourteen and a-half minutes, the speed of the engines being 290 revolutions per minute. The maximum working-pressure was 100 lbs. per square inch.

In the trials teak-wood was used as fuel; the amount required for a full-speed run of eleven hours, was about $1\frac{1}{4}$ ton. The speed attained was 10·49 knots, or just over 12 miles per hour, a very good speed for a boat of that form.

Messrs. Thornycroft and Co. have lately completed a few small torpedo-boats for the Brazilian Government, fitted with guide-blade propellers; their length is 45 feet, and draught 12 inches; and the speed they attained was 15 miles per hour; the extra speed must be attributed to the fact that the hulls were constructed with fine lines.

In Fig. 9 it will be noticed that the performance of the boat with one propeller only running while the other was dragging in the water, gave a better coefficient than when both were running.

The propellers, on account of their positions in the channels, and the casings in which they revolved, are well protected from any injury from floating logs, which abound on the River Congo.

The boat can also rest on the shore without danger of injuring the propellers; and should any one compartment be pierced and filled with water, the boat would still float; adding to this, the safety of the boiler from explosion, it will be seen that the liability to serious accident is reduced to a minimum.

The Authors, in conclusion, wish to express their thanks to Messrs. Thornycroft and Co., for placing at their disposal all the results of experiments and other information necessary for this Paper.

The Paper is accompanied by several diagrams, from which the wood-cuts in the text have been engraved.

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OBITUARY NOTICES.

General EDWARD FRANCIS TODLEBEN was born on the 20th of May, 1818, at the town of Mitau. His life did not begin under favourable auspices, nor would any one have suspected that the son of the Mitau shopkeeper would be numbered with the greatest of Russian Generals. Of Todleben it may well be said that his success was mainly due to perseverance and industry. He received an elementary education at a German private seminary in Riga, and at the age of fourteen he was sent to the Institute of Engineers of St. Petersburg. Owing to ill-health he was prevented from completing the curriculum of that establishment, and returned to Riga. Here he entered the Russian service as an Ensign in the local corps of engineers. In 1840 he was promoted to the rank of Lieutenant, and was transferred to the sapper-training battalion, then under the command of General Schilder, an officer famous for his thorough knowledge of field-engineering and of the construction of earthworks and military mines. Under this able leader Todleben had exceptional opportunities for studying those branches of the profession, to the perfect mastery of which he owed his great reputation.

Todleben received his "baptism of fire" in 1848, when he was sent to the Caucasus, and placed under Prince Argoutinsky-Dolgoroukoff, who commanded the left flank of the army. Thus, at the age of thirty, Todleben came to serve under one of the best Caucasian generals of the time, and went through a course of practical training such as the Caucasus alone could afford. In the operations against Shamil, he on frequent occasions gave evidences of personal bravery, as well as of sound professional abilities, especially at the siege of the fortress of Tchokh, which was conducted under his direction. After two years' active service Todleben returned to Russia, but in 1853, when the Turkish war broke out, he was attached as Adlatus to the Danubian army under General Schilder. At the siege of Silistria, Todleben, now Lieutenant-Colonel, acted as second in command, and on General Schilder being severely wounded, the conduct of the siege devolved on him. When England and France espoused the cause of Turkey, and the rumour flew through Russia that the allies were

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preparing to disembark an invading force in the Crimea, Prince Gortchakoff, the Commander-in-Chief of the Russian army, ordered Todleben to proceed to Sevastopol, and recommended him to the Commandant, Prince Mentshikoff, as a brave and dashing officer and an experienced military engineer, and suggested that the task of fortifying the town and the bay should be confided to him. At first Prince Mentshikoff received him somewhat coldly; but after Todleben had reconnoitred the position, and had sent in his report, the Prince's manner changed, and he was treated with the greatest confidence and respect.

Sevastopol, though well defended towards the sea, was at this period practically open on the land side. The dilatoriness of the allies, in not attacking it sooner, was only equalled by the supineness of Prince Mentshikoff, who refused to believe they really intended a descent, until the battle of the Alma made further misconception impossible. The works were then commenced in hot haste and in earnest. At first the force at Todleben's disposal was very small, but later, when the garrison was augmented, as many as ten thousand men worked in the trenches. The manner in which Sevastopol was fortified has become a matter of history. It has been popularly supposed that Todleben revolutionized the science of fortification, and invented the system of detached earthwork-redoubts subsequently used with such deadly effect by the Turks against the Russians at Plevna, and on which all present systems of fortification are more or less based. This supposition is, however, scarcely correct. Todleben was not the first to discard the antiquated system of Vauban, but he does appear to have been the first to apply the new principles on a large scale. The success of his plan vindicated the correctness of the method, and gave a death-blow to the older forms. In a fortnight Todleben succeeded in erecting so formidable a series of works, that the allies were obliged to abandon the plan of carrying Sevastopol by assault, and found themselves compelled to sit down to an elaborate and laborious siege. The besiegers commenced operations on the 10th of October, 1854, and, from that date until the final taking of the fortress—which did not occur till the 8th of September, 1855, the entire direction of the defensive works was confided to the sole care of Todleben. Every day fresh obstacles were placed in the way of the enemy: batteries were strengthened; a perfect network of counter-approaches was thrown out, and a subterranean war raged near some of the bastions. What caused the allies great losses was Todleben's practice of placing sharpshooters, in detachments of not more than fifty men, in outlying trenches,

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which were generally constructed during the night, and were carried close to the lines of the allies, so that the Russians could fire on the besiegers from under cover.

The name of Todleben now became a household word throughout Russia. He was felt to be the bulwark of the nation. The Emperor Nicholas decorated him with the Order of St. Andrew, and he was rapidly promoted from Lieutenant-Colonel through the successive stages of Colonel, Major-General, and Lieutenant-General, to the rank of Adjutant-General. Nor was he debarred the distinction—which a soldier values more than any decoration—of being wounded in the service of his country. On the 20th of June a ball struck him in the leg, and, owing to inflammation setting in, he was forced to keep his bed. Notwithstanding his sufferings, however, he continued to direct the operations of the defence from his couch, and maintained, amidst the torment of physical pain, that clearness and grasp of mind for which he was ever distinguished. The defence, and its honourable conclusion, will never be forgotten in military history. Well might Prince Gortchakoff say in a general order to the troops: "It is a fact unexampled in military annals, that a town hastily fortified in the presence of the enemy should have been able to hold out so long against a force, the means of attack of which have exceeded everything that hitherto could have been foreseen in calculations of this nature."[1]

Four years later Todleben was appointed a Director of the Engineering Department of the Russian War Office; and when this department was remodelled he was nominated Assistant Inspector-General of Engineering Affairs. This post he retained till 1877, when the Russians remembered that the great master of the system of fortifications which Osman Pasha had adopted, to their confusion, was himself a Russian and still in the country's service. Jealousy was for once silenced, and the veteran was called from his departmental office again to take the field, no longer obliged to restrict himself to the defensive, but invited to plan the attack. He acquitted himself of this task as became the defender of Sevastopol, and showed that during the long years of neglect, though his country had forgotten him, he had not forgotten his duty. He rectified the mistakes of incompetent generals; infused a spirit of harmony where discord had reigned before, and took Osman Pasha prisoner. During the war the two most remarkable Russian generals of

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[1] An official account of the investment entitled "Siege of Sebastopol, 1854–55. Journal of the operations conducted by the corps of Royal Engineers," was published by order of the Secretary of State for War in 1859. A copy of this work is in the library of the Institution.

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modern times, Todleben and Skobeleff, frequently met, and cemented a warm and lasting friendship. In later years, when fighting his country's battles against the Turcomans, the younger general came to value and appreciate the lessons of caution and prudence which his senior had taught him, and by which, as events showed, he had not failed to profit. Nor was Todleben deficient in that daring and love of adventure which was the life of his junior, who greatly admired and respected the dash and personal bravery of the old engineer. Upon the fall of Plevna, Todleben was decorated with the order of St. George of the second class, and after the peace he was appointed Commander-in-Chief of the Russian forces in European Turkey. Like most Russian military men, Todleben felt at that time very deeply what he could not help regarding as the humiliation of stopping before Constantinople, instead of investing it. But he controlled his feelings more soberly than Skoboleff.

Between the Crimean and the Turkish wars, Todleben made several journeys in Europe, and inspected most of the important fortresses of foreign countries. He came to England in 1856, and was very cordially received. He was elected an Honorary Member of the Institution on the 6th of December, 1864, in which year was published his "History of the Defence of Sevastopol," an elaborate work which enjoys a high reputation.

During the last years of his life Todleben was Governor-General, first of Odessa, and subsequently of Vilna. His military education, and habits of discipline and of exacting implicit obedience from subordinates, tended to make him an unpopular administrator at a time when Russian society was in an unusually sensitive condition, and when the stern letter of the law occasionally required an indulgent and elastic interpretation.

General Todleben died at Soden, near Wiesbaden, on the 1st of July, 1884, after a protracted illness. To the last he continued to take the greatest interest in all military questions, and particularly in the equipment and training of the troops entrusted to his charge. The Institute of Engineers at St. Petersburg, in which he had once been a student, has since engraved his name on its walls in letters of gold, with the inscription, "Sevastopol, 1854–5."

EUGENIUS BIRCH was born in London in June, 1818, his father being an architect and surveyor. He was educated at Brighton and at Euston Square. At a very early age he showed considerable mechanical and artistic talent, and was rarely seen

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without a pencil in his hand. He watched with much interest the cutting of the Regent's Canal, and indeed frequently played truant to assist (!) at the construction of the various great engineering works then in progress in the north of London, particularly the Primrose Hill tunnel of the London and Birmingham Railway. When quite a boy, he submitted a model of a railway carriage to the authorities of that line, who had offered a premium for an improvement in this direction, and the Greenwich Railway Company at once adopted his mode of putting the wheels under the carriages. At the age of sixteen, being then employed at Messrs. Bligh's engineering works, Limehouse, Eugenius Birch planned a marine steam-engine, which so pleased Dr. George Birkbeck, that the latter strongly advised the youthful designer to join the local Mechanics' Institute. This he did, and to such purpose that, the master falling ill, he undertook the entire charge of the drawing-classes for some time, to the satisfaction of all concerned. In 1837, he received a Silver Isis Medal from the Society of Arts, for his drawing of a marine steam-engine, and in the following year a Silver Telford Medal and a premium of books from this Institution [1] for his drawings and description of Huddart's rope-machinery. This subject was continued in a subsequent communication descriptive of a "Machine for Sewing Flat Ropes," [2] for which he likewise received a premium.

The encouragement thus given seems to have determined Mr. Birch to adopt the profession of a civil engineer. On the 19th of February, 1839, he was elected a Graduate of the Institution, in which class he remained till he was transferred Member on the 5th of May, 1863, and shortly afterwards he entered into partnership with his elder brother, the late Mr. John Brannis Birch. He was actively engaged in works of varied character until 1845, when the Railway Mania absorbed his whole faculties. On the bursting of the railway bubble in England, Mr. Birch and his brother were engaged in laying out the East Indian Railway from Calcutta to Delhi, designing the whole of the bridges and viaducts, and it was upon the material thus furnished that the guarantee of the line was obtained. Between 1847 and 1851, he designed and carried out the Kelham and Stockwith bridges in Nottinghamshire. But Mr. Birch's claims to recognition are chiefly based upon the system of promenade-piers which he and his brother initiated, and which now form a feature of nearly every watering-place on the English coast. The first, and

[1] Minutes of Proceedings Inst. C.E., vol. i. (1839), p. 6. [2] *Ibid.* (1841), p. 10.

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for many years, single example of screw-pile pier, was the well-known Margate jetty, which was completed in 1853, and formed a new departure in marine construction. It was from the first a most successful work, and has since been considerably improved and extended. Similar piers were subsequently erected from Mr. Birch's designs at Aberystwith, Blackpool, Bournemouth, Brighton (West), Deal, Eastbourne, Hastings, Hornsea, Lytham, New Brighton, Plymouth, Scarborough, and other places. Many of these structures form part only of extensive works of improvement. Mr. Eugenius Birch was also the first to construct a large sea-water aquarium with recreational adjuncts. Of such buildings, those at Brighton and Scarborough are types which have been followed at many other watering-places. The tanks were of much larger dimensions than those previously used, and their construction involved some interesting problems on the pressure of water against large surfaces, and the thickness of material (glass) required to withstand it.

But though provision for the delectation of visitors to the sea-side formed a large part of Mr. Birch's business, it was by no means the whole of it. He carried out the Devon and Somerset Railway, the Exmouth Docks, Ilfracombe Harbour, the West Surrey Waterworks, and was the first engineer of the Scarborough and Whitby railway, which he laid out, although the construction of the works was for long in abeyance, and is now being completed by other parties. His last great design was for a marine kursaal to be erected at the end of the chain pier, Brighton, for which Parliamentary sanction had been obtained; but he did not live to carry out this important work. The design represents a huge ship arranged and fitted up as a first-class hotel.

Had he not chosen to be an engineer, he might have risen to eminence as an artist, being possessed of high talent in that direction. The beauty of his drawings of Huddart's rope machinery, submitted when he was a Graduate, attracted considerable attention, and the artistic faculty remained with him through life. During a tour in Italy, Egypt, and Nubia in the winter of 1874–75, he made a series of more than a hundred water-colour drawings and sketches of such merit that a special exhibition was made of them. After his death, these drawings realized high prices, being assisted, no doubt, by the interest felt at the time in all concerning Egypt. Mr. Birch was a pleasant and genial companion, and a thoroughly honourable man. He died after a long and painful illness on the 8th of January, 1884.

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HENRY ALLASON FLETCHER, of Croft Hill, Whitehaven, who died on the 6th of July, 1884, was born in 1834, and was the youngest son of the late Mr. John Wilson Fletcher, of Tarnbank, near Cockermouth. Mr. Fletcher's family had been engaged in the coal trade of West Cumberland for several generations, and also for some years in the iron trade of that district, which has expanded into enormous proportions during the last quarter of a century. Two of his brothers successively represented the borough of Cockermouth in Parliament.

Mr. Fletcher was educated at a private school. Having been fond of mechanics as a boy, he elected to follow the profession of a mechanical engineer, for which he received the necessary training in the works of Messrs. Gilkes, Wilson and Co., at Middlesbrough. Soon after leaving Middlesbrough he became the Principal and Managing Partner of the Lowca Engine Works, near Whitehaven. These works had been established in 1794 by Heslop and Millward, the original makers of the "Heslop" atmospheric engine, once as well known in the north of England as the Boulton and Watt type of engine elsewhere. In the "Heslop" engine the patent right of Watt for a separate condenser was evaded by the use of two cylinders, one of which condensed the steam from the other. A complete specimen of the "Heslop" engine was some years since presented to the Patent Office Museum, through the instrumentality of Mr. Fletcher, who about the same time gave a full description of the engine in a Paper read before the Institution of Mechanical Engineers.[1] Mr. Fletcher continued to conduct the Lowca Engine Works until the beginning of 1884, when ill-health compelled him to retire, and the works were sold to the Lowca Engineering Co., Limited.

Mr. Fletcher possessed an inventive mind, and took out a number of patents. One was for improvements in the boring and planing of metal; another for specialities in tank-locomotives; and a third for improvements in the permanent-way of railways. "Fletcher's tank-locomotive" acquired considerable reputation.

Mr. Fletcher was a Fellow of the Royal Astronomical Society. It had once been his intention to make a careful study of the heavens, by means of an achromatic telescope left to him by his brother the late Mr. Isaac Fletcher, M.P., F.R.S. Unfortunately the intention was frustrated by the bodily infirmities which seldom

[1] Proceedings 1879, p. 85.

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left him free from suffering during the later years of his life, and which gradually undermined his vital powers.

As long as strength permitted, he freely lent the aid of his ability and good judgment to the furtherance of many useful objects in his own neighbourhood. He had filled the office of President of the Whitehaven Scientific Society, to which he contributed a valuable Paper on the "Archæology of the Iron Trade of West Cumberland." He did excellent service as Chairman of the local Rural Sanitary Authority, as well as in the capacity of Chairman of the School Attendance Committee. He was also Chairman of the Moresby School Board. Indeed, he was ever ready to ally himself with any effort to amend the social condition of those around him. As a county magistrate he did not limit his functions to the attendance of quarter and petty sessions, but he took an active part as an *ex officio* guardian, and as a member of the highway board.

Mr. Fletcher was a man of considerable culture. He was very clever in sketching with pen or pencil, and as a caricaturist had few superiors. Some of his performances in this way found a place in *Punch*. Mr. Fletcher was elected an Associate of the Institution in 1865, and was transferred Member in 1877.

CHARLES FOURACRES was a distinguished member of the Indian Public Works Department, and in all respects so remarkable a man that his career deserves more than a passing notice. A native of Devonshire, in which county the name of Fouracres, spelt in various ways, is well known, and in which his family had long resided, he was in boyhood apprenticed to his father, a builder, and was brought up, and destined by his parents to earn his livelihood in, a carpenter's shop; but from some cause or other he left that occupation and enlisted in one of the East India Company's old European regiments, the 1st Madras Fusiliers, the present 102nd Regiment, a regiment which had the proud distinction of being the first to stem the tide of the Indian Mutiny under General Neill, and which obtained the soubriquet of "Neill's Lambs." Before being transferred to India he married, and, as he himself was wont to say, it showed much devotion in a respectable woman to marry a soldier in those days, for the hardships of a barrack life were far greater then than now. She, however, died after a few years, and at a later period of his life he married a second time. Fouracres had

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not been long in the regiment before his superior intelligence brought him into notice, and his knowledge of carpentry stood him in good stead, for he was selected for the post of Instructor to the boys in the workshops of the Military Orphan Asylum at Madras, and there won the respect of the Chaplain, the Rev. Mr. Lugard, who proved a true friend, and on whom Mr. Fouracres always looked as the first who, holding out to him a helping hand, set him on the bottom round of the ladder, to the top of which he in time raised himself.

After serving a few years in the Orphan Asylum, he was selected by Sir Arthur Cotton as Foreman in the large workshops which had been erected in connection with the great Godavery Delta Irrigation projects. In those workshops Mr. Fouracres showed his special aptitude for training boys, and for communicating the knowledge not only of his own handicraft, but of mechanics in general, as it was not in the art of carpentry alone that he was thoroughly proficient, for he possessed a high order of mechanical genius. It was only necessary to give him a hint of any particular instrument or machine, or to explain to him the kind of work to be accomplished, and his fertile faculty of invention produced not only a machine suited for the work, but one which was generally perfect of its kind. From being Foreman of the carpenters, he gradually came to have control over the whole workshops, under the Engineer-in-Chief, and he ultimately rose to the rank of Sub-Engineer, the highest obtainable in the subordinate grade of the Public Works Department. His devotion to work for twenty years in a trying climate told upon his health, and he became so ill that he was obliged to be sent on sick certificate to England. While at home he made the best use of his time in acquiring a knowledge of all the most recent improvements in machinery. Meanwhile, the East India Irrigation Company had been formed, and the Chief Engineer, Colonel, now General Rundall, knowing the value of Mr. Fouracres' mechanical talents, recommended the Directors of that company to secure his services as an Assistant Engineer for the large workshops which had to be erected at Cuttack, in connection with the great irrigation scheme for the Orissa Deltas. During the six years that the Company continued operations, he rendered invaluable aid. At the time when the Government of India took over the works of the East India Irrigation Company in January 1869, Mr. Fouracres was employed on the Midnapore Canal in the Burdwan district of Bengal; he was transferred from the service of the Company to that of the Government as an Assistant Engineer on those works; but was shortly

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afterwards moved to the Sone Canals, in Behar, which were commenced by the Government in that year. In September 1869, Mr. Fouracres was appointed Executive Engineer of the Dehree workshops; it was in this capacity that he chiefly rendered those services which have been recognized, by both the Governments of India and Bengal, and by the Secretary of State for India, as deserving of special mention and special remuneration. For ten years, from 1869 to 1879, Mr. Fouracres was actively engaged on the construction of all the mechanical appliances for the Sone Irrigation Works. He first constructed the workshops at Dehree, in which the machinery required for the erection of locomotive engines, railway-trucks, mortar-mills, and all the plant necessary for these extensive works, was placed. These workshops comprised steam saw-mills and shops for wood-working machinery, foundry, blacksmiths' and fitters' shops. To a great extent the men employed had to be trained to the work; common coolies on 2 annas (3*d.*) a day had to be instructed to drive portable and fixed engines, and men for fitters' and blacksmiths' work had to be chosen from the supply which the neighbouring villages could offer. In training these men Mr. Fouracres was peculiarly successful; so that in the course of three years a good staff of workmen had been collected and trained. The Sone Canals command an area of more than 1,000,000 acres; the chief undertaking, in connection with these canals, is the anicut or weir across the river Sone. This weir is 12,500 feet between the abutments; it is founded on hollow brick cylinders sunk 10 feet or so into the sandy bed of the river. One of the chief difficulties, at the time this weir was constructed in 1870–73, was to find means to sink the wells in any reasonable time; for in those days the only appliances for well-sinking were of the most primitive description. To overcome this difficulty Mr. Fouracres invented an excavator.[1] This clever invention wrought almost a revolution in the practice of well-sinking in India, and since that day many varieties, all more or less of the same type as that which Mr. Fouracres first used on the Sone weir, or modifications of the original American bucket, have been introduced. By the aid of "Fouracres' Excavator" many thousand wells were sunk in the bed of the Sone, and the weir was thus completed in a fraction of the time that would have been occupied under the old methods. The value of Mr. Fouracres' invention was fully recognized by the Government of India; a special bonus of 10,000 rupees was granted him on account of it.

[1] Professional Papers on Indian Engineering, vol. vii., 1870, p. 23.

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In connection with the Sone weir are three sets of large scouring-sluices, which consist of many consecutive openings 20 feet in width; these are only separated by piers with no bridge above them. Occasionally it is necessary to close the openings when the stream is running through the sluices 8 or 10 feet in depth; at which times a velocity of 16 to 20 feet per second is not unusual. To close these openings Mr. Fouracres designed the hydraulic-brake shutter which forms the up-stream valve, and the tumbler shutter which stands on the down-stream side of each opening.[1] These shutters have now been in successful operation for some ten years, and are justly regarded in India as most effective; they are believed to be unique.

Mr. Fouracres' designs were accepted by Government for all the details of the sluices, valves and other appliances connected with the many locks, weirs, head-sluices, and escapes on the Sone works. Several of them are of novel construction, more particularly an arrangement of rack-and-pinion for opening and closing lock-gates, an extremely simple and efficient means for effecting the purpose. Among the many mechanical appliances for which India has to thank Mr. Fouracres, is the vertical-action bucket steam-dredger. A considerable number of which are now in use in India on canals; those which Mr. Fouracres himself established were constructed with the aid of surplus engines from the plant. These dredgers[2] work at particularly low rates, and have almost superseded the ladder-dredgers which were obtained from England for the Sone works. But while Mr. Fouracres' attention was more particularly given to the mechanical branch of the profession, his abilities were frequently called into play in other directions. On more than one occasion he was specially deputed by the Government to different parts of India to advise on difficulties of various kinds; and whenever the foundations of the many large masonry works on the Sone Canals gave trouble, it was always to Mr. Fouracres' ingenuity and to his large practical experience that the Engineers of these works fell back for advice.

Mr. Fouracres' name will long be remembered in India on grounds distinct from the operations of his purely professional career. He had from the earlier days of his employment in that country taken an active interest in the education of European and Eurasian boys in the mechanical arts; natives also he had not forgotten. Shortly after the Dehree workshops had been placed in good

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[1] Minutes of Proceedings Inst. C.E., vol. lx., p. 47.

[2] Institution of Mechanical Engineers. Proceedings, 1879, p. 534.

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working order, he established, under the sanction and with the cordial assistance of the Government, the Dehree Training School. In this school lads of from thirteen to seventeen years of age were received and educated. The training given was both theoretical and practical; the boys spent part of their time in school and part in the workshops. The success of this school was very pronounced; Mr. Fouracres' share in contributing to this success was, on more than one occasion, acknowledged by the Indian Government in complimentary terms. A special increase of salary was given to him for his part in educating and training European and Eurasian mechanics. Shortly after the Dehree Training School was established he obtained the necessary sanction to found a somewhat similar establishment for natives. In a few months a number of little dusky scholars were to be seen seated on the floor of their school, in the morning repeating the Hindustanee multiplication table; while in the afternoon they spent their time in the workshops, where they chiefly distinguished themselves in the foundry. There these boys, many of them really children, were to be seen busy in the sand, happy and useful; it was surprising how quickly some of them became efficient moulders. Now, many of these children have grown to be mechanics far superior to their fathers in practice and in learning.

In 1879, when the Sone works were approaching completion, it was determined to establish a large Government workshop in Calcutta, and to transfer the Training School to that city. About this time the Indian Government offered special bonuses and pensions to engineers in order to reduce the overgrown establishments. Mr. Fouracres took advantage of these terms and sent in his papers. His resignation was accepted, and he obtained the advantages then offered. But the Government were unwilling to lose his services, and although he nominally left the Department of Public Works he never actually did so; for on the day following that on which his name was struck off the permanent list, it was placed on that of the Temporary Engineers. Mr. Fouracres was in fact immediately re-employed on special terms for the Calcutta workshops. His health, however, again failing, he was obliged once more to visit England, but as soon as his strength was recruited he returned to his post.

In Calcutta, or rather at Seebpur on the right bank of the Hoogly opposite Calcutta, Mr. Fouracres again went through the labour of building new workshops, importing and erecting new machinery, collecting his staff of workmen, and generally superintending the arrangements of a new factory. The Dehree

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Training School was transferred to Seebpur, where it formed a section of a large college which was started mainly to give a superior engineering education. This college is a branch of the Calcutta University, and the scholars see something of practical work in the shops. These new workshops at Seebpur were but just fully completed, equipped, and in working order, when, at the commencement of 1884, Mr. Fouracres was suddenly seized with a slight attack of paralysis, and was finally compelled to leave India. At this time the Government of India again recognised the exceptional nature of Mr. Fouracres' services, by recommending to the Secretary of State in Council that a special pension, in addition to that which was due under the terms of the concessions of 1879, should be granted to him. This request was acceded to, and in a form, which, as it occurred, was a peculiarly fortunate one. A bonus of 15,000 rupees was given to Mr. Fouracres "on account of the great mechanical ingenuity which he applied unremittingly in the service of Government, and the saving effected by some of his inventions." He, however, did not live to receive this bonus himself; he died suddenly at Bristol on the 14th of July, 1884, aged fifty-eight. Of these fifty-eight years over thirty-two were spent in active employment on the plains of India.

No Government was ever served more faithfully and profitably than was the Indian Government by Charles Fouracres, and while he was an example to all in the singleness of purpose and fidelity with which he discharged his public duties as a servant of the State, in private life he commended himself to, and won the respect of, his fellow-men, by the kindliness of his disposition, his readiness to oblige and assist all who asked his aid, and by the general geniality of his character.

To the youths under his own special care he proved a kind and considerate master, taking a personal interest in each individual boy, and winning their affection in return. By his brother engineers in India the name of "Old Fouracres" will long be held in kindly remembrance, while their warmest sympathies are extended to the widow and family left to mourn his loss.

The esteem in which he was held by all classes cannot be better expressed than in the following letter, from the Bishop of Calcutta:—

"Palace, Calcutta.
"May 20th, 1884.

"My dear Fouracres,

"I was very sorry not to see you again before you left the country, as I should have liked to have expressed to you more fully than I have done how much indebted I feel to you for all your good work done during your long period

of service in India. Others can speak (and I have no doubt they have spoken) more fully as to your professional services, but it does not require an engineer to discover how much you have done to make the Eurasians and natives appreciate honest manual labour. Indeed the complete revolution produced in the minds of many of them on this subject has, so far as Bengal is concerned, been accomplished in a great measure through your exertions. You know how interested I always have been in the lads under your charge in the Seebpur College. But as Bishop of the Diocese I must also speak of the excellent moral and religious influence always exercised by you over the lads, and in this respect it is only simple truth to say that I miss you. I hope some one may soon be raised up to fill your place. Give my kind regards to Mrs. Fouracres. I hope you have recovered your health, and that you have found a comfortable sphere of duty at home.

"Yours faithfully,

(Signed) "EDWARD R. CALCUTTA."

Mr. Fouracres was elected a Member of the Institution on the 2nd of December, 1879.

ROBERT SAMUEL FRASER was born in North Shields, in Northumberland, on the 26th of October, 1829. His father—of Scotch descent—was an officer in the Mercantile Navy, and died while Mr. Fraser was a youth. His mother was the daughter of Mr. Thomas Chicken, an engineer well known in the North of England, and who was engineer to the proprietors of the Monkwearmouth Colliery, in the county of Durham, during the sinking of that celebrated mine and for many years afterwards.

From his parents Mr. Fraser inherited the excellent qualities which, from his earliest years, endeared him to his friends and marked his professional life from first to last; and it is probable he derived from the maternal side the remarkable physical and mental energy, and devotion to his profession, which was the reason for his singular success as an engineer.

At about fourteen years of age he was apprenticed engineer to Mr. William Clark, of Sunderland, a friend of his grandfather. Here he was distinguished by great energy and intelligence, and he had barely passed through his apprenticeship when he was made Principal Foreman of the works of Mr. George Clark, of Sunderland.

Mr. Fraser, though of middle height, united to a well-made and closely-knit figure, a frank and even bold countenance, and a clear eye, great physical strength; attributes which, regulated as they were by an intimate knowledge of working men, and a firm will, made him most successful in the management of men; a thing on

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which his heart was fully set, and on which he hoped to build future success.

In about his twenty-fifth year he characteristically determined to start business on his own account, and would certainly have succeeded; but, shortly after, and while he was struggling with the initiatory difficulties of such enterprises, an event occurred which changed the entire course of his professional life.

The Crimean war had been in progress more than a year, and had made such demands upon the siege artillery, as to render useless all classes of iron guns through the destruction of their vents. The Government thereupon determined to fit up a screw steamer as an engineer's workshop, or "Floating Factory" as it came to be officially described, completely equipped with men and appliances, for, in the first place, re-venting guns of every calibre then in use in the siege works before Sebastopol, and others that had been already removed from the batteries, wherever they might be lying; and in the next place to render such services as it was believed such an establishment could do to the Ordnance Department of the Army, the steamships of the Navy, the Land Transport Corps, and the Army Works Corps. A committee was appointed by the War Minster, consisting of the late Admiral Sir Richard (then Captain) Collinson; the late General (then Col.) Tulloch of the Carriage Department, Royal Arsenal; General (then Major) Collinson, R.E.; and Sir (then Mr.) John Anderson, of the Machinery Department of the Royal Arsenal, to whom was delegated the duty of purchasing and equipping such a vessel, and the appointment of the manager, on whom would devolve the manifold duties indicated above, and on whose skill, tact, and ability the success of the experiment would depend.

The committee purchased the s.s. "Chasseur" from Messrs. T. & W. Smith, of Newcastle-on-Tyne; a vessel designed for a collier, about 170 feet long, 27 feet beam, and 17 feet deep, supplied with engines of 70 HP., and of about 700 tons burthen. The committee then went in quest of a manager, and through Sir William (then Mr.) Armstrong, of Elswick, found and appointed Mr. Fraser to the delicate and difficult post. The equipment of the "Chasseur" with machinery was completed under his personal direction, and the staff of artificers was selected by him, comprising smiths, carpenters, engineers, plumbers, iron-founders, brass-finishers, brickmakers, and sadlers. The "Chasseur" left the Tyne on the 29th of August, 1855, and reached Balaclava on the 26th of September. The fall of Sebastopol having occurred before her arrival, the main object in her equipment no longer

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existed, viz., that of re-venting guns of position in the works. The secondary objects, however, existed in abundance. The Land Transport Corps, under Colonel MacMurdo, just then taking measures for the approaching winter, found the advent of the "Chasseur" most opportune, and warmly welcomed Mr. Fraser; the Army Works Corps, under Mr. Doyne, particularly in the railway department, looked on the arrival of the "Floating Factory" as that of a strong ally; the huge fleet of steam-transports also, and the steam vessels of H.M. fleet using the harbour of Balaclava resorted to the "Chasseur" for help, and to these various bodies Mr. Fraser, by his tact and skill, made his vessel immensely useful, and by degrees, a necessity.

His position was anomalous and curious. The "Floating Factory" was an experiment, belonged to none of the regular branches of the service, and, had she failed in the purposes for which she was sent out, might easily have sailed home again without any one in the service being injured by it. Mr. Fraser, however, saw his opportunity, and determined to make it the stepping stone to his future career. On arriving at Balaclava Mr. Fraser had orders to report himself to the Port-Admiral (Freemantle), who received him kindly, and gave the "Chasseur" a berth, from which she could not move, nor communicate with the shore, without his permission. The "Floating Factory" was attached to the railway department, which paid but did not feed its staff, nor did anything else for it but countersign some requisitions. It was chiefly appropriated by the Land Transport Corps, which had no official claim on it, and was fed by the Commissariat department by means of requisitions drawn upon one department and countersigned by others.

The channels by which demands for the services of the "Chasseur" reached Mr. Fraser were not less intricate. Colonel MacMurdo would requisition Mr. Doyne, whose order might require the Admiral's countersignature, and so on, all which, to a non-service man, made the situation puzzling and difficult. Gifted with indefatigable energy, however, and with a natural grace of manner—which gave to his comparative youth in such a position of grave responsibility a certain dignity—Mr. Fraser found the way through all difficulties to make himself extremely useful to all who had need of the services he could render, so that when the "Chasseur" was ordered home, after the close of the war in 1856, he received from all the departments the most gratifying recognition of his valuable services. Colonel MacMurdo issued a general order in which he stated that he could not allow

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the "Floating Factory" to close its relations with the Land Transport Corps till he had testified to the value of the services Mr. Fraser had rendered to his department of the service.

On his return to England, the report rendered by Mr. Fraser to the War Minister as to the amount of work performed by the "Chasseur" had several remarkable results. It led to his entire staff being each paid an honorarium of six months' salary on leaving the service of the Crown; to the "Chasseur" being added to the establishment of H.M. Navy; and to Mr. Fraser being appointed as Assistant to the Inspector of Machinery in the Arsenal on the "Chasseur" being paid off.

Soon after Mr. Fraser's appointment to the machinery department, the Government adopted the gun and its manufacture introduced by Sir William Armstrong, which led to the transformation of the Royal Gun Factories, from the comparatively small foundry and machine-shop in Dial Square, into the magnificent works of which the department now consists. To this department Mr. Fraser was appointed Manager in 1859, while Sir William Armstrong was Superintendent; and again on the appointment of Sir John Anderson as Superintendent, Mr. Fraser was appointed (in April, 1866) Deputy Assistant-Superintendent. While the gun factories were being re-cast—almost re-created—Mr. Fraser's energy and practical engineering knowledge proved of great service to the department, as may be inferred from his successive appointments; but his right to a distinguished place in the profession rests on more specific grounds than this.

The Armstrong gun had not been long in the service before it was found to be susceptible of some improvement. Being built up of a number of coils of various lengths, one coil shrunk over the other to obtain the requisite thickness, and overlapping to attain the required length, the overlaps were found to yield under firing, and allowed a slipping action to take place. It was also doubted whether the number of coils one over the other was practically beneficial, owing to a case in which the outer coils split under fire while the inner ones remained uninjured. Another and equally important question was suggested, viz., whether the material used in the gun needed to be so expensive as the iron used in making the comparatively thin coils.

Mr. Fraser's knowledge of materials and of constructive mechanics led him to conclusions on all these points; these were tested by experiment, and eventually the service gun which bears his name, and since, without material change of construction, called the Woolwich gun, was produced, to the credit of

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which Mr. Fraser is entitled. This gun is described in the later text-books. "Until April, 1867, all our rifled M. L. guns were built up like the B. L. guns—of wrought iron coils shrunk together successively on Sir William Armstrong's original plan. The plan proposed by Mr. R. S. Fraser, of the Royal Gun Factories, was then adopted; but manufacture on the original construction did not cease altogether until March, 1868.

"Mr. Fraser's plan is, as stated in a previous chapter, an important modification of the original method, from which it differs principally in building up a gun of a few large and comparatively heavy coils instead of several short ones and a forged breech-piece.

"For example, in addition to the steel barrel and cascable, a 'Fraser' 12·5 inch R. M. L. gun has only four separate parts, viz., the breech coil or jacket, *B* tube, the 1 *B* coil and breech-piece, whereas the 7-inch R. M. L. gun of original construction has a forged breech-piece, a *B* tube, a trunnion ring, and six coils—nine distinct parts—which are shrunk on separately (see Mark I., Plate IX).

"The formation of a heavy coil is a simple forge operation, but great expense is saved by its means, as there is much less surface to be bored and turned, for each coil having to be made as smooth as possible, and at the same time true to gauge (to a thousandth of an inch), it follows that it must be cheaper to have a few thick ones in lieu of many thin ones. For the same reason there is also less waste of material; for although the turnings are afterwards worked up into bars, iron in its scrap state is only worth one-third of its forged value.

"Moreover, time and labour are also saved in having fewer pieces to move from workshop to workshop; for instance, in the case of a gun of original construction, when a coil was shrunk on, the mass had to be moved from the shrinking pit to the turning-lathe, and turned down for the next coil, and so on, coil by coil, until the gun was built up; but in the Fraser construction only two or three separate shrinkings are required.

"From these circumstances, combined with the employment of cheaper iron, a Fraser gun can be made more cheaply than a gun of the same nature as originally manufactured, while the experiments which were carried out previous to the introduction of this construction clearly prove that guns of this pattern are at least quite as trustworthy and serviceable as those of the original pattern."

The "Fraser" manufacture and construction has since per-

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vaded the entire service, and though steel is now superseding iron, the system of building the gun has not been materially changed.

The State on two occasions very fittingly recognized the valuable services rendered by Mr. Fraser, by presenting him on each occasion with £5,000.

Of Scotch descent, his name was originally spelt Frazer, but in 1866 he had it legally changed to Fraser. Though of an exceptionally robust constitution, he contracted a severe attack of pleurisy about fifteen months before his death; during his convalescence his retirement was decided upon, and though it was effected on a liberal scale, it did not enable him to regain health, and he died after he had left the service only about two months.

His singular gentleness and vivacity in private life, his penetration, and the almost epigrammatic piquancy and terseness of his language, his great fondness for animals (always a special trait in him), and affection for his friends, marked his whole life. He was elected a Member of the Institution on the 6th of December, 1864. Throughout his professional life he enjoyed the friendship of many eminent members of the learned, scientific, and literary professions, who, with other friends sincerely mourn his comparatively early removal.

RICHARD GARRETT,[1] the fourth bearer of that name in succession, and one of a family which has given three members to this Institution, was born on the 22nd of July, 1829, at the Works House, Leiston.

The subject of this memoir was educated at an old-fashioned private school at Wickham Market, where he attained a popularity which still survives. A boy of unusual personal attractions and influence, untiring energy and courage, his school-life was in itself a little history upon which those who participated in its events look back with pride and pleasure.

At the age of fourteen, however, Richard Garrett left school to embark, under formal indentures of apprenticeship, upon that best of all educations for an engineer, the post of apprentice-assistant to his enterprising father, who, in the development of Leiston

[1] The substance of this memoir is taken from notices in the *Suffolk Chronicle*, the *Engineer*, and other papers of August, 1884.

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Works, stood in urgent need of such assistance. It need scarcely be said that the influence of so promising a pupil soon took effect at Leiston Works, and at an age when most lads can be scarcely said to regard life seriously, Richard Garrett the younger, was to all intents and purposes Works-Manager—a position of which he took formal occupation on attaining his majority in 1850. In 1853 he became a partner with his father and younger brother, John D. Garrett, who seceded from the business in 1860; and on the death of his father in 1866, Mr. Garrett succeeded to the position of head of the Garrett family and senior member of the Leiston firm, in partnership with his two brothers, Henry Newson Garrett—who also seceded from the business in 1878—and Frank Garrett, between whom and the subject of this memoir there existed bonds of close attachment.

Richard Garrett may be stated generally to have devoted his life to the construction and development of the thrashing-machine —first as a horse-power implement, and later as the finishing machine, otherwise termed the combined thrashing, dressing, and straw-shaking machine, and the merits of his celebrated invention, patented in combination with the late James Kerridge, the then foreman of the thrashing-machine department at Leiston Works, under date 18th January, 1859, No. 153, still finds high appreciation in all quarters of the globe. Under this arrangement, the wind employed for the two or three blasts necessary at different intervals in the preparation of the grain for market by the combined machine, is produced by one fan, which is keyed upon the same spindle as the thrashing-drum, and the blast is conveyed to the needful points of contact with the grain through wooden channels. The advantage of such a system—which was probably suggested to the inventors by the arrangement adopted in all large smithies for the blowing of the fires by one large fan instead of by a multiplicity of bellows—is so apparent, that it only needs to be added that the practical difficulties attending the application of the invention were completely mastered, in order to make its value understood.

Next to the thrashing-machine, the portable steam-engine may be said to have been the object of Richard Garrett's engineering life; and perhaps no man had a more thorough knowledge of the subject. Resolute in all his dealings and opinions, a most careful and trustworthy mechanic, and a perfect manager of workmen, firm and just and charitable, it is difficult to say whether he was most beloved or most respected by his men; and the old hands

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are still working at their benches at Leiston who helped him to carry the Leiston portable engine forward through its multiplicity of stages to its present prominent position. Mr. Garrett's opinions were applied with characteristic vigour to matters of mechanical construction, and he never adopted a form of construction because it was simply "fashionable." As an instance of this characteristic, allusion may be made to one point in particular, in respect to which the Leiston engines differ from those of most other leading makers. Nothing would induce Mr. Garrett—at one time even at the risk of a most valuable connection—to construct the commercial portable engine, in which steam is only used expansively to a very limited extent, with a steam-jacket. Mr. Garrett had satisfied himself that a steam-jacket was under such conditions misapplied, and consequently he refused to sacrifice his conviction upon the altar of fashion. As a young man he used to read a great deal, especially on the subject of the steam-engine, and other mechanical constructions, and although he was only known, as an engineer, by the practical results of his ingenuity, the latter was tempered by a sufficient admixture of sound theory to make his efforts singularly free from error. He was also much opposed to automatic expansion as applied to portable engines, and to the undertype of semi-portable, and these forms of construction he never hesitated to condemn. Of the compound-system of expansion in double-cylinder portable engines he was as resolute an advocate; and although the credit of instituting this arrangement may be directly attributable to his brother and surviving partner, still the enterprise was undertaken under the highly interested approval and advice of Richard Garrett.

Another instance may be noted of steadfast adherence to his convictions. He was strongly opposed to the prize-system of the Royal Agricultural Society, as applied to agricultural machinery in general, and to portable steam-engines in particular; and from 1859 onwards he consistently declined to assist at these, as he maintained, misleading competitions.

Notwithstanding the high reputation Mr. Garrett had as an agricultural engineer, he was better known among his neighbours as a tenant-farmer. As a practical agriculturist he held high rank, and the Carleton Hall stock has become famous in bucolic circles. At the time of his death he occupied something like 2,000 acres of land, the greater part of which lay in West Suffolk. He held a strong opinion that the sporting rights should be combined with the cultivation of the land—an opinion

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which drove him to the western side of the county, where he accepted a tenancy on Mr. William Angerstein's estate, near Brandon, just on the Suffolk side of the Ouse. The Suffolk cart-horse was the object of Mr. Garrett's especial care and study. His enthusiam took a practical form when, in the year 1869, the sale of Mr. T. Crisp's Butley Abbey stock nearly occasioned the loss to Suffolk of the finest specimen of its breed (Cupbearer). At 300 guineas the horse was just on the point of being knocked down to a gentleman who desired to take it to a distant colony, when Mr. Garret secured the animal at 370 guineas. This has, for all time, made his name one to be remembered by Suffolk farmers and horse-breeders, and the Cupbearer stock bears testimony to the lasting service he did to the county. His collection of prize cups, which form a special bequest to his brother Frank, and were won chiefly by Cupbearer and his almost equally famous successor, Cupbearer III., is, perhaps, unrivalled in the county as an agricultural collection. Mr. Garrett was also a breeder of Suffolk sheep, and possessed an excellent and improving herd of shorthorn cattle, which have added not a little to his other trophies. He took an active part in the Suffolk Agricultural Association, of which he had been for some years prior to his death a vice-president. He was likewise a prominent member of the Smithfield Fat-Cattle Club. In 1877 he joined with Mr. A. W. Crisp and Lord Waveney in advocating the compilation of a Suffolk Stud-Book, and when the Suffolk Stud-Book Association was formed he was made a member of the committee. Whilst he was a large receiver of prizes, he was also a liberal donor, and many local shows have been much indebted to him for encouragement. One of his last acts in the agricultural world was to offer, in conjunction with his brother, Mr. Frank Garrett, the prize of the day at the first show of the Framlingham Association for the breeding of Live-Stock. The offer of the prize, which assumed the form of a challenge cup for the best cart-foal exhibited by a tenant-farmer in the show-yard, was a good example of the interest shown on his part in the encouragement of breeders of useful stock. Another feature in Mr. Garrett's career, which increased his popularity amongst agriculturists, was the prominent position which he took in sporting matters. He was an excellent and steady shot, and for many years rented a moor in Scotland, in the neighbourhood of Inverness—a rugged spot on which, to him who was disposed to overcome difficulties of progression, plenty of excellent grouse-shooting was to be had, and afforded an entertaining means of

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spending a holiday to many of Mr. Garrett's friends and relatives. For the last few years of his life, however, the exertions of sport in this part were too much for his failing health, and a substitute was found in Mr. W. Angerstein's sporting-manor. In the hunting-field Mr. Garrett was a familiar figure, and those interested in it will remember him for his plucky riding. No less remarkable was he for the persistency and untiring energy with which, against heavy odds, he struggled to maintain fox-hunting in his game-preserving county.

As a young man he rode to hounds regularly twice a week throughout the season. He was also a great advocate of pugilism in the days when no discredit was attached to the prize-ring, and as an amateur he is said to have had no equal.

In politics Mr. Garrett was a pronounced Conservative and vigorous supporter of the County Members. The Liberal tendencies of commercial enterprise were not strong enough to overcome his Tory preferences. He was a great advocate of the Rifle Volunteer movement in Leiston, and was one of the first to join the local corps. He served for ten years, at the end of which time, having attained the rank of Major, he retired from the service amidst general regret. He might well be styled the father of the Leiston corps, for not only did he join it in its infancy, but he was always liberal when money was required for the maintenance of the funds. His zeal for the welfare of Suffolk farmers naturally made him take an interest in the Albert Memorial College, at Framlingham, which was intended expressly for the benefit of the agricultural community. Ever since the death of his father in 1866 he took a prominent part in the work connected with the College, and enjoyed the position of Governor. Of late, though retaining his office, he retired from active work in this direction, partly from failing health, but chiefly from the knowledge that now that the school was well established it was no longer in need of the active exertions which he had formerly made on its behalf.

In reviewing Mr. Garrett's career it is impossible not to be struck with the wide area over which he gained fame and esteem. As an engineer his name is known by the whole agricultural population of the world, while in his native county he enjoyed the greatest popularity among all classes. A successful farmer, a capital judge of cattle and horses, a popular major of volunteers, an active politician, and a genial neighbour, he threw into his pursuits, for the time being, all his ardour. Such a character never fails of recognition in any part of the world, and least of

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all in England. It is easy to understand the feeling of sorrow with which the news of his death was received, not only by his friends and neighbours, but also by those who had met him in business, either as an engineer or as a farmer.

Mr. Garrett was elected an Associate of the Institution on the 7th of March, 1854, and was transferred to full Membership on the 30th of October, 1877. He died suddenly, after some months of serious indisposition from heart-disease, on the 30th of July, 1884.

ANDREW JOHNSTON was born in Cursitor Street, London, in 1818, and was educated at Grant's, Crouch-end, Highgate. He served a pupilage, commencing in 1836, under Mr. Christopher Davy, of Furnival's Inn, and then passed two years with Mr. Hythe, architect, of Worthing, and afterwards was engaged by the late Mr. Vignoles, Past-President, Inst. C.E. In 1845 he was employed by the late Mr. J. U. Rastrick, M. Inst. C.E., to assist Mr. John Underwood on the Parliamentary work of the Ambergate, Nottingham, and Boston Railway, and was the Resident Engineer of part of that line between Nottingham and Grantham, including the building of the bridge over the river Trent, until its completion in 1851. Next for three years (1851–54) he was occupied upon the drainage of Dartford and the present waterworks at Croydon, under Mr. Ranger of the General Board of Health. For five years (1854–58) he was in practice as a civil engineer at Nottingham, in partnership with his old friend Mr. Underwood, during which time they made the extension of the Nottingham and Grantham line from Colwick into Nottingham, which was part of the Great Northern system, being their main line from London to Nottingham. In 1858 Mr. Johnston became Assistant-Engineer on the Brighton Railway under Mr. R. Jacomb Hood, M. Inst. C.E., where he remained until July, 1865, when he accepted the post of Principal Assistant-Engineer on the Midland Railway, under the late Mr. J. S. Crossley, M. Inst. C.E., having charge of the whole of the maintenance of the line. On the resignation of Mr. Crossley in 1875, Mr. Johnston was appointed Engineer to the old lines, a position he retained until the autumn of 1883, when declining health, due largely to his unceasing attention to the Company's interests, necessitated his resignation. The Company granted him a liberal pension, and his brother officers and staff presented him with a handsome service

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of plate. His friends hoped that he would be long spared to enjoy the fruits of his labours; but his well-earned repose was short, as just six months after his retirement he succumbed to a stroke of paralysis, leaving a wife and large family.

Mr. Johnston was of an extremely retiring and reserved disposition, so that the number of friends enjoying his intimacy were few. Exceptionally well trained, a thoroughly practical engineer, steady and reliable, most conscientious in all his dealings, he was a most valuable assistant and officer. He was elected a Member of the Institution in 1875.

THOMAS MARTIN was the second son of the late Aylmer R. Martin, a solicitor practising in Cork and Dublin, and was born on the 13th of June, 1831, at Mayfield, Co. Cork. He was educated at Bandon school, and from thence entered Trinity College, Dublin, on the 14th of September, 1848, where during his under-graduate course he distinguished himself at each honour examination in science, always obtaining honours in mathematics, and came out from the final examination as second Senior Moderator and Gold Medallist in Science, 1852. He also obtained Bishop Law's Mathematical prize in 1853. Having selected engineering as his profession, he passed the usual course in the engineering school of Trinity College, obtaining the diploma of the school and a special certificate of merit. He then served a pupilage of one year to Mr. W. R. Le Fanu, M. Inst. C.E., now one of the Commissioners of Public Works for Ireland, during part of which time he was Assistant Resident Engineer on the Mallow and Fermoy Railway, at that time in course of construction. In 1859 he entered the service of the Bombay Baroda and Central India Railway, in which he continued for nearly four years. In 1863, on account of his mathematical attainments, he was appointed to the Calcutta Civil Engineering College, where he officiated as Principal. In 1864 he was made a Fellow of the Calcutta University. At the end of that year he entered the Public Works Department as an Executive Engineer, second grade. He was, in the first instance, posted to Assam, but his health suffered from the climate, and in 1865 he was compelled to take furlough home, and while there was elected a Member of the Institution on the 4th of December, 1866. Shortly after his return to India in 1867 he was transferred to

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the Punjab, and was employed on the remodelling of the Western Jumna Canal, having in the meantime been promoted to Executive Engineer, first grade. In the years 1871–73 he officiated for various periods as Superintending Engineer of the whole of the Western Jumna Canal, the great Sirhind Canal, and of the lower portion of the Baree Doab Canal. In 1874 he was deputed to Bengal in connection with the relief-works rendered necessary by the famine of that year. He had the supervision of such works as the embankments of the Gunduk river as Superintending Engineer, and received the thanks of Sir Richard Temple for his efficient management of them. He retained this charge after the famine, and returned to the Punjab in 1877, where he remained in the active discharge of his duties as an engineer in the irrigation branch till his death, which occurred at Mean Mir, from Delhi fever, on the 19th of December, 1883. He was an excellent mathematician, an energetic officer, and a good engineer; very successful in pushing on work. Mr. Martin was of a genial and kindly disposition, and was loved and esteemed by many friends in this country and in India. These are at present engaged in erecting a memorial tablet to him in the cathedral of his native city Cork.

JOHN JAMES MONTGOMERY, born at Ballymore, in County Westmeath, in the year 1832, was the eldest son of Mr. John Montgomery, now residing in Liverpool, but formerly connected with the Coast and Boundary Surveys and the General Valuation of Ireland. His maternal grandfather was Major Nethery, of the 27th (Fermanagh) Regiment, who was killed in the Peninsular War, at the siege of Tarragona. His early education was received at some of the best classical and scientific schools in Ireland. Subsequently he became a student at Queen's College, Belfast, where he obtained the first Scholarship in Civil Engineering. Being delicate, and the climate of Belfast not appearing to suit him, he removed to Cork and entered the Queen's College there; here again he distinguished himself. Leaving Cork he went to London and obtained a practical knowledge of his profession in the office of the late Mr. C. B. Lane, M. Inst. C.E., of Westminster, and after this received an appointment at the Royal Observatory, acting as private secretary to Sir George Airy, acquitting himself with ability, and to the entire satisfac-

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tion of the late Astronomer-Royal. His first engineering engagement was at Blackburn, where he was largely occupied with the drainage of the borough and other municipal operations. On leaving Blackburn he was appointed chief assistant to Mr. Charles Gott, M. Inst. C.E., the Borough Engineer of Bradford, where, in addition to the ordinary duties of his office, he was engaged, in conjunction with that gentleman, in the construction of the extension of the water-supply of the town—a work of considerable magnitude.

The office of Borough Engineer of Belfast became vacant in 1861, and Mr. Montgomery was successful in obtaining the appointment. Belfast at that time was a town of some 121,000 inhabitants. The population at the last census was 208,122, and is still rapidly increasing. It required all Mr. Montgomery's energy to keep pace with the long strides which Belfast made during these years, but the present aspect of the town shows that he was equal to the strain thus demanded of him. In 1866 Mr. Montgomery designed an extensive scheme for the arterial and outfall drainage of the borough. This scheme was referred to Mr. (now Sir Joseph) Bazalgette, President Inst. C.E., who fully approved of it, suggesting but slight modifications. A large portion of the arterial drainage has been carried out under Mr. Montgomery's superintendence, but the main outfall-works remain in abeyance. In the early days of Mr. Montgomery's career in Belfast the low-lying districts of the town were continually subject to flooding. He set vigorously to work to overcome this evil, and by a system of storm-overflows, tidal-valves, and skilful dealing with the several water-courses traversing the Borough, so far succeeded that flooding is now of comparatively rare occurrence. The rapid development of Belfast of late years has necessitated the laying out and paving of several hundreds of new roads and streets, involving the construction of many miles of tributary sewers, all designed to harmonize with the general scheme of drainage above referred to. The local Act of 1878 gave power for the diversion of the River Blackstaff, which has a watershed of about 8,400 acres. Although this river is fed by rapid and variable streams descending from the neighbouring hills, within the Borough it occupies a flat valley almost coinciding in level with the lowest part of the town. Along its banks are situated large mills and other manufactories; and the water-rights of some of these being materially interfered with, many difficulties presented themselves in the design and construction of the works of diversion.

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The old river course traversed in a serpentine route a large district somewhat centrally situated, but for the most part unoccupied by buildings, owing to the presence of a tidal river contaminated with impurity. The new covered course consists of two culverts, each 12 feet wide, constructed with heavy ashlar walls and invert and brick arches, the whole covered with concrete. A new street, 70 feet wide, over the new river course, has been opened for public traffic since Mr. Montgomery's death. The Blackstaff diversion was a favourite scheme of Mr. Montgomery for many years, and it is satisfactory to know that he lived to see it an accomplished fact.

Another extensive work carried out under the local Act already referred to, was the removal of several hundred tenements in a densely populated part of Belfast, and the opening up of a thoroughfare 80 feet wide and about 1,600 feet long. This work was accomplished under Mr. Montgomery's direction, and although the street lines laid out are not quite in accordance with his own views, the undertaking has been a notable success, as but few vacant building lots now exist. The buildings since erected have been four storeys and upwards in height, including several important public and Government edifices.

The foregoing are only leading instances of many important works of municipal engineering and town-improvements achieved under Mr. Montgomery's term of office in Belfast, and they are the best evidences of his skill and foresight, sometimes under difficulties and in face of opposing opinions. In the Parliamentary Committee-rooms he was well known, and his evidence in engineering matters was always received with respect and often with a compliment. In 1878 Mr. Montgomery was offered an important engineering appointment in Brazil at an annual salary of £2,000, but after mature consideration, and on material inducements being offered by the Belfast Corporation, he resolved to remain at his post. One of the last problems to which he had addressed himself, was an extensive scheme for deepening and embanking the tidal portion of the river Lagan, situate above the harbour of Belfast.

Mr. Montgomery was elected a Member of the Institution of Civil Engineers on the 7th of February, 1871, and always entertained a keen interest in its proceedings.

His death was as sudden as unexpected. In August, 1884, while travelling alone in the vicinity of the St. Gothard Tunnel, he was seized with a severe illness, which terminated fatally in three days, at Airolo, and he was interred at the English Protes-

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tant Cemetery in the suburbs of Lucerne. His name is cherished by many, and by none more than his brother officers and professional friends. At a meeting of the Town Council of Belfast on the 1st of September, a resolution was unanimously passed in expression of regret at the loss, in Mr. Montgomery, of a valued officer and adviser, and directing a letter of condolence to be forwarded to his widow.

GEORGE HENRY PHIPPS, jun., who was born at Brixton on the 23rd of May, 1840, was the only son of George Henry Phipps, M. Inst. C.E. His early education was pursued at the Stockwell Grammar School, which was in connection with King's College, London. There he gained a scholarship, which led to his removal to the College, where he remained for two years, passing very creditably through the regular curriculum of a scientific education suited for the profession of a civil engineer. After this, in accordance with the advice of his father's friend, Mr. Robert Stephenson, Past-President Inst. C.E., he served three years as an apprentice to the firm of Messrs. Robert Stephenson & Co., Newcastle-upon-Tyne. It may be observed that the course to be gone through in such an apprenticeship involves some hardships. The latter portion of his time, however, was occupied in the drawing office. The advantages of the discipline of the workshop consist in the apprentice becoming acquainted with the nature of the materials used, and the construction of the machinery, only attainable by having the work pass through his own hands. Having passed through the above course in all respects satisfactorily, at the end of his apprenticeship he became a pupil of the late Mr. J. F. Tone, M. Inst. C.E., for more than a year, after which, for nearly two and a half years, he was employed by Mr. T. E. Harrison, Past-President Inst. C.E., on the works of the North Eastern Railway. Subsequently he was employed by the Consett Iron Company, for about a year and a half, in the construction of railways and buildings; and then, for about a year, by Mr. George Berkley, M. Inst. C.E., in designing ironwork, &c. From April 1870 to April 1871 he was employed by the Messrs. Waring Brothers on the East Hungarian Railway, under vicissitudes of climate (floods, and extremes of heat and cold), and physical difficulties of no ordinary character. From May 1871 to August

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1873, he acted as Maintenance-Engineer on the Recife and São Francisco Railway at Pernambuco, in Brazil, making also a survey for an extensive new line of railway. In October 1874 he was one of a party of engineers appointed by the Government of the Cape of Good Hope, under the recommendation of Mr. (now Sir) Charles Hutton Gregory, Past-President Inst. C.E., the Engineer-in-Chief. The appointments were for the purpose of the construction of a comprehensive system of railways at the Cape, there being at that time only a line of about 70 miles in length at Cape Town. Arrived at the Cape, it was arranged that Mr. Phipps should be connected with the eastern portion of the lines, and thus he went to Port Elizabeth, and was then occupied with trial surveys on the Graaf Reinet line, and also on the Grahamstown line, a branch line laid out from Grahamstown to a junction with the Cradock railway, immediately after crossing the Bushman river at Bushman's Poort. These trial-surveys, and the subsequent staking out of the lines, generally involved very arduous work, from the party having to pass through thick "bush," in one case of 20 miles continuous length. On the Grahamstown branch the "staking out" was very troublesome, as, owing to the rocky nature of the soil, the stakes could not be driven, and holes had to be formed by means of steel jumpers. The surveys and staking out having been completed, the construction of the line was commenced, Mr. Phipps having charge of the lower portion of the Grahamstown branch.

Great difficulties were experienced in the construction of the bridge at Bushman's Poort, owing to the floods in that country, which come down very suddenly, and in large volume. A temporary bridge had to be constructed strong enough for the locomotives and wagons to pass over for the conveyance of materials. The temperature also, sometimes 120° in the shade, made the work very trying. It is admitted that the works of masonry, &c., on the branch line were well and solidly constructed, and this under difficulties from the drunkenness and insubordination of the workmen and labourers employed (some native, but many from England), such as are fortunately unknown in England, and, it may be added, not without danger to the lives of those who, like Mr. Phipps, always insisted on proper work being done.

His next employment was upon the upper portion of the Cradock line, where, after more trial-surveys, a portion of the line was started under his own charge, without a contractor, and a tunnel was commenced. The line was afterwards contracted for by Messrs. Faviell. After this Mr. Phipps went to Port Elizabeth

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to take charge of the work of another engineer sent to make some surveys. There he remained up to July 1882, having to construct various buildings, with charge of the maintenance of the lines of railway, &c. At that date he was promoted to a superior position in connection with the extension of the main lines from Cape Town to Kimberley, then completed to Beaufort West. The surveys up to August 1882, in the hands of Mr. E. W. Young, M. Inst. C.E., were then carried on across the arid district known as the Karoo for 150 miles in length, under the directions of Mr. Phipps. The surveys having been completed, various bridges and other works were commenced on this line, one of these being a bridge over the Modder River, situated some 50 miles from the Orange River, north-east of Hopetown. It consisted of eight spans of 80 feet each, with masonry piers of from 35 to 40 feet above the rocky bed of the river. The bridge was considerably advanced on the 16th of February, 1884, and was to be completed with an iron superstructure. Mr. Phipps had just returned from a journey of inspection over the works on the 1st of March, when he was attacked with typhoid fever which terminated his busy career. He died at Rustenberg House, Rondebosch, near Cape Town, on the 10th of April, 1884.

Thus terminated, after twenty-four years' work from the date of his apprenticeship to Messrs. Stephenson, the life of the subject of the present memoir, to the keen sorrow of his family, who were counting upon his early return from the Cape, where he had been employed for nearly ten years without a break.

Mr. Phipps was a hard worker, possessed great perseverance and administrative power, and gained the respect and esteem of all with whom he was connected, both professionally and privately. Mr. Phipps was elected a Member of the Institution of Civil Engineers on the 4th of December, 1883.

JAMES ELDRIDGE was born at Seddlescombe, Sussex, in 1814, and was educated at the Westminster Training College as a schoolmaster. He was appointed to a school at Newent in Gloucestershire about 1837, and remained there till 1852. Here he did a considerable amount of land surveying, chiefly in connection with agricultural matters, but occasionally on railway surveys; he was also engaged on the gasworks at Newent. In 1853 he was employed by Mr. R. P. Spice, M. Inst. C.E., upon extensions being

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carried out at the Richmond, Wandsworth, Kingston-upon-Thames, Watford, Hoddesdon, and other gasworks; and in the following year took sole charge of the Richmond Works for Mr. Spice, who was then lessee of them. In 1864, the lease having expired, the directors appointed Mr. Eldridge their Engineer and Manager, and there he remained till his death on the 31st of May, 1884. During his connection with the Richmond Gas Company, he twice remodelled and rebuilt the works to meet the increasing requirements of the town. Always desirous of introducing any improvements in the manufacture or purification of gas, he was the first to adopt exclusively the use of West's stoking apparatus; and his own adaptations of Coffey's Still as a washer attracted a good deal of notice among gas-engineers. He was one of the promoters of the Southern District Association of Gas-Engineers and Managers. The preliminary meeting was held at his house, and he was President during the first year. He was also one of the oldest members of the Gas Institute, and took an active part in the management in its earliest days. He was elected an Associate of the Institution of Civil Engineers on the 7th of March, 1871, subsequently being transferred to the Associate Member class, and was also a Member of the Society of Engineers, of the Society of Arts, and a Fellow of the Royal Meteorological Society. One of the Richmond papers thus refers to Mr. Eldridge's death: "It is not often that the local Press has to record the death of one so generally respected as Mr. Eldridge, the well-known Engineer to the Richmond Gas Company. Owing to an amiable modesty, his merits were not so well known as they deserved to be; but no higher praise could be bestowed on his Christian worth than the kindly remark of one who knew him intimately (in, as well as out of business), that he was even a better man than he seemed to be. His influence over the not always very promising labour element with which he was associated, was distinguished by so gentle and persuasive a firmness that he won the goodwill and respect of many who would have resisted severity, and who can well bear loving testimony to the practical value of his kind and wise words in reforming their characters and saving their pockets. There are those who think sermons may only be effectual through licensed pulpits and State-regulated channels, forgetting that the lives of good men, such as James Eldridge, may be a daily sermon prompted and sanctified by the Great Teacher Himself."

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FREDERICK AUGUSTUS SHEPPARD was born at Brighton, in 1819. After receiving a portion of his education at the Grammar School, Horsham, he completed it under a private tutor. He learnt the rudiments of surveying from Mr. Thomas Hughes, one of Telford's trusted assistants, and subsequently under his brother, Mr. R. Sheppard, then practising in Horsham. His first employment was for about two years by Mr. Joseph Gibbs, M. Inst. C.E., on the survey of a projected line to Brighton. He was then engaged for three years with Mr. J. Wright, of Aylsham, upon numerous surveys for the Tithe Commutation Commissioners. In 1841 he accepted an offer from the New Zealand Land Company, and took charge of surveys, laying out townships, and marking out roads, &c. After a stay of three years in the colony, urgent private business caused his return to England. Mr. Sheppard was engaged on several of the proposed lines of railway in 1845, and executed a series of surveys for Messrs. Harris and Brounger of portions of the Eastern Counties Railway. In 1847 he was engaged by Mr. Alfred Giles, M. Inst. C.E., on surveys at Southampton Docks. This led to an appointment as Resident Engineer on the Reading, Reigate, and Guildford Railway, for superintending the line between Dorking and Guildford. On the transfer of this line to the South-Eastern Railway, that Company retained his services for nine years. On a change in the engineers' staff of the South-Eastern Railway, Mr. Sheppard left the Company's service, and in 1857 entered for a time that of Mr. John Fowler, Past-President, Inst. C.E., by whom he was mostly employed on the surveys of the Severn Valley line. He shortly after again was engaged for Mr. Giles upon the works at Southampton Docks, and afterwards on surveys in Denmark for proposed lines of railway, and in the following year, 1858, in Switzerland upon surveys, &c., of the proposed Lukmanier railway from Coire to Olivone. In 1860 Mr. Sheppard accompanied Mr. Giles to Canada, and assisted in the examination, &c., of the Great Western Railway. On his return to England he was offered by Sir John Coode, M. Inst. C.E., the appointment of Assistant Engineer to the works in Table Bay, Cape of Good Hope, then being carried out under the charge of Mr. A. T. Andrews, M. Inst. C.E. At the close of that year Mr. Sheppard reached the colony, where he remained in the Government service for six years, till the completion of the work. While in the colony Mr. Sheppard passed all the examinations required for the certificate of qualifications in the theory of civil engineering, and was registered "Sworn Government Sur-

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veyor;" and he also passed the higher examination as "Cape Civil Engineer," being the first person to whom that grade was given. Returning to England, he obtained from the Colonial Secretary of State the appointment of Deputy Colonial Engineer and Comptroller of Convicts of the Straits Settlement. Mr. Sheppard proceeded to Singapore in 1867, and remained there until 1872, when a change in the department being made, his office was abolished, and he received a small pension. After being occupied on some mining surveys, Mr. Sheppard was sent by Messrs. Wythes and Jackson, in 1873, to Demerara, to survey and report upon a proposed line of railway to Berbice, but upon his report the undertaking was not carried out. Mr. Sheppard was next engaged by Mr. John Gardiner, M. Inst. C.E., upon surveys for railways in South Wales, and having been introduced to Mr. J. Gabrielli, was sent by him in 1874 to China, to report upon the proposed railway from Shanghai to Woosung. He made the necessary surveys; set out the line, and constructed the greater portion of the embankment, when the work was stopped. In the following year he accompanied Mr. Gabrielli to Rio Janeiro, respecting the enquiries for the proposed new water-works at that place. Having completed his work in Rio, Mr. Sheppard received instructions from the firm of Krupp and Co., of Essen, Prussia, to proceed to Buenos Ayres and make arrangements for the construction of a line of railway to Bragado; but the Government abandoned the project. On his return in 1876, he was immediately engaged in superintending the construction of a line of tramway from Blenavon to Abersychan; and on its completion Mr. Sheppard was, for the fourth time, employed by Mr. Giles as Assistant Engineer on the construction of the new graving dock at Southampton. When this was finished, in 1879, Mr. Sheppard joined the firm of Burleigh and Green as their Engineering Manager. In this capacity he superintended the new pier-extension at Southampton, as well as works in London, and several extensive tramway undertakings. He next surveyed a line from Bologna to Verona, and, after a short time spent upon the Abbotsbury Railway, he proceeded to Halifax, Nova Scotia, to survey for a new graving dock. Here his health, which had been for some time failing, broke down. He returned to England in a prostrated state, from which he never recovered. He gradully sank, and died in London on the 18th of August, 1884.

Mr. Sheppard was of a most unselfish nature, and gave honest and conscientious service to his employers, and in the public offices which he filled; in many cases he suffered loss himself,

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rather than act contrary to strict principles of honesty and integrity. He was elected an Associate of this Institution on the 6th of December, 1853.

CHARLES HENRY GRAHAM SMITH (Graham Smith), was born in London on the 23rd of May, 1851. Shortly afterwards his parents visited Australia, and his education was commenced at the collegiate school of the Rev. G. Macarthur, Macquarie Fields, New South Wales. Returning to England, in 1864 he was placed at King's College School, where he remained till October, 1866, when he was articled for three years to Messrs. Neilson and Co., of Glasgow. There he acquired a thorough practical knowledge of mechanical engineering, and at the same time continued his studies by the aid of masters in the evenings, working both in the shops and class-rooms with that earnestness which was one of his distinguishing characteristics. He then spent six months under Mr. John Fowler, Past-President Inst. C.E., in studying the construction of the Metropolitan District Railway. In 1870 he was further articled for two years to Mr. George Fosbery Lyster, M. Inst. C.E., Engineer-in-chief to the Mersey Dock and Harbour Board, and had varied experience in the construction of dock and other engineering works, buildings, sewers, and the maintenance of roads. From May to November 1872 he was employed on the contractor's staff of the Isle of Man Railways during their construction; and in the preparation of the Parliamentary deposits of the Gloucester and Ledbury, and the Nettle Bridge Valley lines of the Great Western Railway Company. After this, till October 1873, he assisted in Mr. Fowler's office in the preparation of the designs for the disposal of sewage at Malta, the Egyptian irrigation, and other extensive works. He next became assistant to Messrs. Blyth and Cunningham, MM. Inst. C.E., under whom he was engaged on designs for extensive works on the Caledonian Railway during the Carlisle Citadel Station improvements, and the Central Station works at Glasgow. He left this situation in August 1874, to become Resident Engineer under Mr. Lyster during the restoration of the Liverpool floating landing stages and bridges, which had been destroyed by fire, and on the construction of the south reserve floating landing stage and piers at Birkenhead; and in 1877 he was occupied on designs and parliamentary work for the Liverpool Overhead Railway. At the end of this year he removed to Westminster, and commenced

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private practice, which he continued to the close of 1881; meanwhile for eighteen months of this period he acted as Secretary to the Association of Municipal Engineers. Having obtained the appointment of Engineer to the Port Commissioners of Rangoon, British Burmah, he proceeded thither, and besides general routine maintenance work, he erected several screw-pile jetties, with floating pontoon bridges, and reclaimed a large quantity of land. The Government also borrowed his services for a time to inspect and to advise on the improvement of the Moulmein river. Unfortunately, however, some differences having arisen between the Port Commissioners and himself, in which many of his professional friends considered he had been unjustly treated, and the anxiety of his position, in addition to the effects of the climate, having broken down his health, he resigned the appointment and returned to England in May 1883. In May 1884 he was employed by Messrs. John Fowler and Co., to proceed to San Francisco. He returned in July, and was making arrangements for a permanent residence in that country, when he was stricken down by his last illness, and he died of abscess on the liver, on the 9th of September, 1884.

Mr. Graham Smith was admitted a Student of the Institution on the 5th of April, 1870; and while attached to that class was successful in obtaining two Miller Prizes; on the first occasion, for a Paper on "Practical Ironwork," and on the second, for a communication on "The Design and Construction of the South Reserve Piers and Floating Landing Stage at Birkenhead."[1] He was elected an Associate of the Institution on the 6th of March, 1877, and was afterwards transferred to the class of Associate Members. Besides the communications for which he received the Miller Prizes, he was the Author of several works on engineering subjects which were published, also of some addresses which met with a favourable reception. He was the founder of the Liverpool Engineering Society, of which he was President in 1876 and 1877, and afterwards Honorary Life Member. Mr. Graham Smith was clever, well-informed, and very persevering. He had an intense love for his profession, and was always most earnest and conscientious in the performance of everything that he undertook; while his uprightness and integrity, his gentleness of manner, and kindness of heart, obtained for him the respect and love of all his friends.

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[1] Minutes of Proceedings Inst. C.E., vol. l., 1877, p. 164.

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SPENCER HERAPATH was the second son of John Herapath, the mathematician, and cousin of the noted analytical chemists, William Herapath and Dr. William Bird Herapath. He was born in 1822, and early indicated that he shared the mental gifts of his family. Having received some mathematical training from his father, he proceeded to the United States, passing his time chiefly in a college in Indiana. On his return he was for a time connected with "Herapath's Railway Journal." He afterwards became a member of the Stock Exchange, and the head of the firm which he established of Spencer Herapath and Co. some forty years ago.

Mr. Herapath was noted for his knowledge of railways and public works, for the study of which he had a natural aptitude. This led to his election, on the 5th of March, 1867, as an Associate of the Institution; he was a Fellow of the Statistical Society, the Royal Geographical Society, and a Member of the Society of Arts. He took part, as Director and otherwise, in Argentine, Brazilian, and Australian railway undertakings, in which his opinion had great weight.

He exhibited sound judgment in his own investments, having for many years, and to the time of his death, held largely in the valuable Buenos Ayres Great Southern Railway, the City of Buenos Ayres Tramways, the Great Western of Brazil Railway, in all of which he was a director, and in the Central Argentine Railway. He was also an authority on many questions of foreign loans, sturdily maintaining principles of credit. For many years he was a member of the Committee of Spanish Bondholders. He took, with his brother, Mr. E. J. Herapath, great interest in his father's labours, and had designed a new edition of the Mathematical Physics, and to publish his minor works. Ill-health in later years, and the pressure of business, prevented the fulfilment of this design.

It should be added that, in his earlier days, he acted as private secretary to Admiral Laws, at that time the manager of the Lancashire and Yorkshire Railway. He was also Secretary of the Sheffield, Barnsley, and Wakefield Railway, and on his retirement from that position received the following testimonial of his services:—

Extract from the Proceedings of the Parliamentary Committee of the Sheffield, Barnsley, and Wakefield Railway Company.

(Dated) Office, Wakefield,
26th December, 1865.

Mr. Herapath, the Secretary, having tendered his resignation to the committee.

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Resolved:—That the same be received, and that the thanks of the committee be given to Mr. Herapath for his zeal in the service of the company, and that three months' salary in addition to what his services up to the 31st inst. would amount to, be placed at his disposal.

True extract.

J. Charles Handfield, *Secretary.*

Of the subject of this notice, it may be said that whatever he undertook, he excelled in, and it is deeply to be lamented that death, at a comparatively early period, cut short a career of usefulness to those around him, and of advantage to an important section of the public.

Mr. Herapath died on the 13th of March, 1884, aged sixty-two years.

THOMAS WILLIAM KINDER was born in London on the 10th of November, 1817, and was educated at Dr. Fennell's, the Temple, Brighton. He was appointed ensign in the Worcester Militia in 1840, lieutenant in 1846, and captain in 1853. His regiment was one of those embodied during the Russian war and Indian Mutiny, and he served continuously with it until its disembodiment in 1859, when he was transferred to the 3rd West York Militia, which remained embodied till the end of 1860. He thus, in his varied career, had seven years' uninterrupted experience of military life, and possessed, in addition, a considerable acquaintance with the minutiæ of regimental duties, and the principles and tendencies of army organisation. He remained in the 3rd West York Militia until 1870, when he retired with the rank of major. In 1845 he established railway-works at Bromsgrove and Oldbury, of which he was for ten years a partner, and subsequently conducted the locomotive department and working of the Shrewsbury and Birmingham Railway. From 1851 to 1855 he had the management, under lease, of the Midland Great Western Railway of Ireland.

Major Kinder was appointed Master of the Royal Mint, Hong Kong, in 1863, the entire organization, construction, and working of which institution he carried out with remarkable energy and approved ability until its suppression in 1868, at the instance of the Governor, the late Sir R. G. McDonnell.

At about this period the Japanese Government, desirous of placing the national currency upon a solid basis, and urged strongly in this direction by the British Minister at Yedo, who

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clearly saw how necessary this step was before the domestic and international exchanges of the empire could be satisfactorily conducted, entered into negotiations with the Hong Kong Government for the purchase of the plant of the disused Colonial Mint, which was at once transferred to Japan. The high character borne by Major Kinder as a successful organizer and clear-sighted Mint-Master, recommended him to the then Finance Minister of Japan as the Director of the new institution, which rapidly took shape under his hands. The difficulties he had to encounter in this work were of an exceptional character, and demanded a combination of qualities with which it may safely be said few men are endowed in so ample a measure as was Major Kinder. But one by one all these difficulties were surmounted, and he gave to the empire of the Mikado a coinage of high artistic merit, redounding equally to the wisdom of His Majesty's advisers and to the administrative powers of his Mint-Master. The empire was at this time in the throes of revolution, and Osaka, where the new Mint was erected, was not far distant from the provinces still held by some of the most powerful of the daimios, who maintained the declining cause of the Shogûnate. It may easily be believed that the safety of his buildings and treasure caused Major Kinder no ordinary solicitude, and he planned and superintended the erection of barracks in the neighbourhood of the Mint, which guaranteed it effectually against dangerous surprises. He added gasworks to the establishment, and subsequently erected works for the production of sulphuric acid, which have since proved very lucrative to the Japanese Government.

Major Kinder had the honour to receive the Mikado at the Mint, and subsequently had three or four audiences of his Majesty, one being on leaving Japan in 1875, when the Mikado publicly thanked him for his services. During his stay in Japan, he, in conjunction with the Finance Minister, Enouye Bunda, originated the postal department in that country, and with the same Minister was instrumental in organizing a system for alleviating the miseries of the poor. He also laid the first stone of the Masonic Hall at Kobé, and was its first Master.

Major Kinder was elected an Associate of this Institution on the 4th of December, 1860. He had an intimate knowledge of mechanical details, with a far-reaching apprehension of results. Of an energetic character, and possessing great diplomatic tact, had scope been given him, he would have attained a more prominent position.

Major Kinder latterly resided at Torquay. He died suddenly,

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from disease of the heart, at the Norwood Junction station of the London, Brighton, and South Coast Railway, on the 2nd of September, 1884.

JOHN HORATIO LLOYD was born at Stockport on the 1st of September, 1798. He was the son of John Lloyd, who was an attorney and Town Clerk of that town, a man of remarkable energy of character, and a Tory of the old school, intensely loyal to Church and King. He took a very active part in putting down the Luddite insurrection, and for his services rendered to the Government was appointed to the ancient office of Prothonotary of the counties of Chester and Flint. His eldest son was born at a time when Lord Nelson was the popular hero, and on this account the name of Horatio was given to him. He received his first education at the Grammar School of Stockport, and at once showed great aptitude for learning, especially in the Classics, which at that period, even more than now, formed the groundwork of education. When about twenty years of age he assisted his father in his efforts to restore order, and in later days used frequently to speak of those stirring times. His father was hated by the lower class of the people of Stockport, and on one occasion owed his life to the circumstance of another man being shot in mistake for him. At the time Mr. Lloyd was away from home, in another part of the town, and his son John Horatio went to warn him that the people were much excited against him, and to recommend him to return home by back-streets. This, however, Mr. Lloyd positively refused to do, and, accompanied by his son, he marched through the streets, which were filled by an angry and excited mob, who gnashed their teeth at him with rage, but forbore to attack him.

John Horatio Lloyd was sent up to Oxford in 1818, and matriculated at Queen's College. His father, whose professional interests had suffered by his untiring exertions in the cause of the Government, had not the means of maintaining his son at the University, but the expenses were privately met, with well-timed generosity, by Lord Sidmouth, a Minister of the Crown, and Mr. William Hobhouse, the brother of Lord Broughton. The advantages thus acquired were not thrown away upon him, for in the year 1822 he obtained a first-class both in classics and mathematics, after which he was made a Fellow both of Queen's and Brasenose Colleges. He remained at Oxford two years longer, taking pupils, of whom he had always as many as he could undertake.

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He took his degree as M.A. in 1824, and then came up to London in order to study for the Bar. He was called to the Bar at the Inner Temple on May 6th, 1826, and on the 1st of September of the same year he married his cousin, on his mother's side, Caroline, daughter of Holland Watson, a magistrate of the counties of Chester and Lancaster, and Major of the Stockport volunteers.

He joined the North Wales circuit, and gained a considerable practice there. He soon became well known in London, both on account of his legal abilities, which obtained very early recognition, and also from his earnest interest in politics. He was a member of, and frequent speaker at, the Union Debating Society, where he was associated with J. S. Mill, Charles Buller, J. A. Roebuck, the late Lord Clarendon (then Mr. Villiers), and his brother, and many others whose names have since become famous. He entered Parliament in 1832, after the passing of the Reform Bill, when he was returned for Stockport, then a new borough, in the advanced Liberal interest. He took part in many interesting debates, arguing in 1833 against giving magistrates the power of summarily convicting in cases of felony, and supporting a petition presented by the attorneys of Westminster for a committee of inquiry into the conduct of the Benchers of the Inns of Court, relating to the admission of students to the Bar. He also took a leading part in connection with the Patent Bill of the same year, the subject of patents having always been one of great interest to him; and in 1834 he introduced a Bill to abolish the punishment of death for setting fire to buildings where life was not endangered. His efforts were especially directed towards the mitigation of the severity of the punishments which at that time disgraced our criminal code. He used to relate that, on one occasion when he was on circuit, a poor woman was tried for her life for stealing a loaf of bread. Shoplifting was at that time very prevalent, and the presiding judge was determined to exercise the full rigour of the law. The circumstances were such as to awaken the compassion of all present in the court, many of whom were visibly affected, whilst Mr. Lloyd remained dry-eyed. A friend turned to him, and said, "Lloyd, what hard-hearted fellows you and I must be, that we are not in tears." "Tears! I am too indignant for tears!" was the reply. Such an outrage to humanity could not fail to give a powerful stimulus to philanthropic efforts in the direction mentioned. He also, when in Parliament, voted for any measure that was brought in for the better government of Ireland. He was, at that time, an ardent Radical; and there was, indeed, much that needed thorough reform. It was his hatred of oppression, and his

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desire to secure the just rights of the people, which enlisted him in the ranks of the reformers. In later days he used to say that all the measures he had then advocated had become law; but he remained a consistent Liberal to the end.

His health gave way under the double strain of a long practice, and the keen contests of Parliamentary life, and at the ensuing election he did not again offer himself as a candidate. He retired for a short time from the exercise of his profession, but when his health was re-established he returned to the Bar. The rapid development of the railway system in 1845 largely increased his practice, and he soon became known as the chief authority in all legal matters connected with railways. His chamber practice became enormous, and he was employed as counsel for nearly all the railways in the United Kingdom. Although a sound lawyer, he never suffered himself to be trammelled by mere technicalities, but looked on questions from broad principles of equity. Thus he would often find a way out of difficulties which would have embarrassed a man more timid, or of narrower views, and it was owing to the counsel given by him that many important schemes were brought to a successful issue, which must otherwise have been stopped. It was by his advice that the means were found to establish a new company for laying the Atlantic cable, when the promoters seemed to have come to a dead-lock; and in the same way he devised the well-known security called "Lloyd's Bonds," without which a large proportion of the existing railways could not have been constructed. It was looked upon with suspicion by lawyers at first, as an evasion of the law. It was, however, too simple and too equitable to be set aside, and is now generally adopted.

Mr. Lloyd was a very able speaker, and required very little preparation for his speeches. He had great clearness of perception, and could at once seize upon the main points of a case. These his excellent memory enabled him to retain and to bring out in due order. Having once made up his mind what to say, the words came of themselves, and it was perhaps owing to his extensive acquaintance with the masterpieces of English literature that he was always choice in his language. He prided himself on speaking thoroughly correct English. He was also a clever examiner; his endeavour being not so much to extort confessions from unwilling witnesses, as to lead them to confession before they were aware how far they had committed themselves.

His practice brought him into connection with all the leading engineers and contractors, with many of whom he lived on terms

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of great friendship, and in whose society he always found much pleasure. He took a lively interest in the engineering profession, and became an Associate of the Institution of Engineers in 1860, and was a member of the Council in the Session 1867-68. For some time he was a frequent attendant at its meetings, but advancing age and infirmities obliged him to give this up, although for some time longer he continued to interest himself in their concerns. He had the satisfaction, very shortly before his death, of seeing his youngest grandson, Archibald Scott Napier, admitted a Student of the Institution.

Mr. Lloyd had a family of eight children, four sons and four daughters. Five of his children, including all his sons, preceded him to the grave, three of them having died in infancy. He lost his second son, Frederick Watson, in 1862, at the age of thirty-three. He was a barrister on the South Wales Circuit, and a young man of great promise, and as he inherited many of his father's tastes, the loss of his affectionate and congenial companionship was keenly felt. In 1874 another heavy blow fell upon him in the death of his eldest son, Horace, a Queen's Counsel, and one whom he anticipated would have attained to the highest honours of the profession. This was followed, in 1875, by the death of his wife, to whom he was tenderly attached. He was then an old man, and although he still retained the vigour of his intellect, he was gradually breaking down, and work was more of an effort to him than formerly. He had always been subject to attacks of gout, and as he grew old his nervous system was very much affected by this malady. He retired from the practice of his profession at the close of 1876. To one of his active mind, the loss of a regular pursuit was a trial. When he was in good health, however, his time passed happily. He was extremely domestic in his habits, and his resources of mind, and intellectual tastes, were a sufficient recreation to himself, and an element of pleasure to those around him. He was an extensive reader, and preserved his love for the classics to the last. Music, painting, and English poetry were always a source of great enjoyment to him, and he excelled especially as a reader of Shakespeare. He was fond of society, and his genial temper, ready sympathy, and keen sense of humour made him a general favourite. He loved especially to have young people about him, and had the knack of always setting them at their ease with him. Although a man who thought for himself, he was a sincere Christian, and a consistent member of the Church of England. Thus, in his old age, he was honoured and beloved, and the smile with which he greeted his friends will

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long be remembered by them. When he was turned eighty his bodily infirmities increased rapidly upon him, but his mind was still clear, and his memory good.

In the autumn of 1882, he was taken seriously ill at Spa, in Belgium, with an attack of congestion of the liver. He never quite recovered from this illness. From October 1883 he failed rapidly, and for the last few months of his life scarcely left his room. He did not suffer much pain, but his good spirits quite deserted him, and before the end came he had grown very weary of life. He passed away quietly on the morning of July 18th, 1884, in the eighty-sixth year of his age. He was buried at Hendon, where his wife and two sons had been laid to rest before him, on the 23rd of the same month.

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Sect. III.

ABSTRACTS OF PAPERS IN FOREIGN TRANSACTIONS AND PERIODICALS.

Account of the Swiss Precision-Levelling. By R. Guisan.

(Compte-rendu de la Société des Ingénieurs-civils, 1883, pp. 637–680.)

As the Swiss were obliged to base all their levellings on bench-marks whose values were fixed by their neighbours, very contradictory results [1] were introduced into their work. An international goedetical commission was accordingly held at Berlin in 1864 to frame rules for precision-levellings which should be common to all central Europe. At this it was resolved that side by side with the trigonometrical determination of heights, these levellings should be executed by the method of equal sights, the necessary checks being obtained by the polygonal combination of stations. The Swiss portion was commenced in July 1865, under the direction of Messrs. Hirsch and Plantamour (the directors respectively of the Neuchâtel and Geneva Observatories), and it will be finished this year (1884).

The instruments used were Ertel's levels on a modified form, having telescopes magnifying forty-two times, fitted with three horizontal stadia cross-hairs, the angle subtended by two threads being about 3′ 30″. Each of the twenty divisions of the bubble scale was tested by the meridian-circle at Neuchâtel, and corresponds to about 3 seconds of arc. The staves, which are 3 metres long, are made of very dry pine and graduated to centimetres, black and white alternately, the even numbers being written on one side, the odd on the other; these staves are provided with a box-level and plummet, and their feet are tipped with an iron cylindrical spur which fits in a hole pierced in an iron tripod. The staff-holder grounds his staff firmly by a blow of its butt, after which it can be rotated without fear of displacement between the back and fore sight. On bad ground or in wind the staff is braced to keep it truly vertical.

Before commencing field work, as also at its close, the three instrumental constants are very carefully determined; they are:—

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[1] As an instance it may be mentioned that from four comparisons *with France alone*, the value of the benchmark of the stone of Niton at Geneva was found to be 374·452 metres, 374·133 metres, 374·052 metres, and 373·252 metres respectively. Comparisons with Germany, Austria, and Italy would give totally different values from the above.

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1st. The angular value of the bubble scale-graduations.

2nd. The angular reduction of the mean of the three threads.

3rd. The angular distance of the two outer threads.

The method of doing this is detailed at length by the Author, and he further shows clearly that, by the system of levelling adopted, curvature and refraction may be safely neglected.

The staff-length is a most important factor in levelling, and this was most carefully and frequently tested. To find the equation for the two staves per metre, two benchmarks in bronze were let into the rocks in front of the Neuchâtel Observatory at a difference in height of 2·90 metres. The instrument was set up exactly midway between them (at 30 metres), and their difference in level was read on each staff successively at varying heights of the instrument. The absolute staff-length was tested by the standard at Berne, and this latter will be compared this winter (1883-1884) with that at Paris, when, on the completion of the levelling, final values will be given to all the readings taken. From the comparisons already made, the staff-length is not affected by moisture, and only very slightly by temperature; its changes are not proportional to the interval elapsing between the comparisons, nor are they systematic, as they vary accidentally as much in one direction as in another.

The principle of completely separating the observations from the calculations was adopted. The original field-books are copied, the originals being sent to Neuchâtel, and the copies to Geneva, where the reductions are made in duplicate. To simplify the work and reduce the expense, the polygon system is adopted, and where this is impossible the line is levelled twice over. The work is repeated, in either case, if it does not close satisfactorily. Amongst the chief rules of procedure are the following:—

1. The levelling to be executed by equal sights whenever possible; the difference between length of back and fore sights never to exceed 10 metres.

2. The length of sight is as a rule to be limited as under:—
   (*a.*) Upon railroads with gradients under 1 in 100 to 100 metres.
   (*b.*) Upon railroads with steeper gradients from 50 metres to 100 metres.
   (*c.*) Upon highroads in the plains from 30 metres to 60 metres.
   (*d.*) Upon mountain roads, from 10 metres to 25 metres.

3. The spirit-level to be always shaded from the sun.

4. The three instrumental errors, viz., collimation of optical axis, inequality of pivots, and bubble-error, to be determined at least once a day.

5. The field-work to be carried on continuously except on wet or windy days; 3 kilometres at least should be the length of line levelled per day along railways, and 2 along roads in the plains.

6. Bench-marks to be made at every kilometre, and to be clearly described in the field-book.

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For adjustment of the errors made in the field Messrs. Hirsch and Plantamour have applied the method of least squares on the following principle. Two approximations are obtained, and both are based on the supposition that the closing error of a polygon equals the arithmetical and not the algebraical sum of the errors made in its different sides. This supposition, though not exact, is necessary for the solution of the conditional equation. Two values for the correction to be applied to a side are found from each polygon of which it forms a part; one value by taking into account accidental errors only; the second by taking into account errors due to change of length in the staves. The probable mean of the correction for each side is then obtained, and, by comparing each individual value with this mean, allowing for the weights assigned, the mean error of each correction is found. The closing error having been thus reduced, the second approximation is applied, in which the mean error of the correction found by the first approximation is taken as the measure of the accuracy of the different sides. Fresh corrections, as well as the mean errors of such corrections, are again obtained, and with these new values the closing errors of the various polygons are reduced to a minimum. An example is given in illustration, as also a Table, by which it appears that in six sides, together measuring 272 kilometres, the mean error per kilometre is below 1 millimetre.

In verifying work either by duplicated levelling or by closed polygons, a discrepancy of 0·0007 metre per kilometre in the two results is allowed on favourable ground, and of 0·0050 metre on unfavourable. In the Swiss work, the mean error per kilometre has consequently been:—

1. In duplicated levelling:—
   (*a*.) On ten favourable lines measuring 416 kilometres, 0·0014 metre.
   (*b*.) On twenty unfavourable lines, measuring 830 kilometres, 0·0085 metre.
2. In nineteen closed polygons, whose sides measure 6,693 kilometres, 0·0030 metre.

Levelling lines the second time in the opposite direction has sensibly improved the closing of polygons.

During the progress of this work twenty benchmarks have been placed on the boundaries of countries conterminous with Switzerland, and it now only remains for an international congress to agree upon a common datum level, which should *a priori* be a point along the Mediterranean, to allow a comparison between the precision-levellings of all central Europe.

E. H. C.

[NOTE.—In a note the Author remarks that the settlement of the instrument makes the fore sight less than it should be, and proves from the levelling of thirteen lines with steep gradients that the difference in level is invariably greater in ascents than in descents. Mr. Hirsch, however, replies that in a work he is now engaged on this question is fully discussed, but that the effect of settlement—all other things being equal—depends rather on the length of the line levelled than on its difference in level.—E. H. C.]

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A System of Prisms for Spirit-levels with detached Bubble-tubes.

By Colonel GOULIER.

(Bulletin de la Société d'Encouragement pour l'Industrie nationale, vol. xi., 1884, p. 97.)

This adjunct to spirit-levels, designed by Mr. Klein, and constructed by Mr. Berthélemy, though far too delicate and of little use for ordinary work, is of the highest importance in precision-levelling, since it removes one of the causes of error in that branch of surveying, its object being to ensure the exact centering of the bubble at the moment of observation. In Gravatt's spirit-level this advantage is gained by a small mirror hinged above the bubble-tube at any required angle, but this arrangement has not been generally adopted.

The bubble-adjustment is not, however, so stable as many suppose, and is easily and often largely upset by the movements of the observer round the instrument; in fact, when one of the legs of the level is in the line of levelling, the displacement of the bubble varies from 1 millimetre to 50 millimetres on a staff 100 metres distant, according as the legs rest on pavements or on vegetable soils; even on railway ballast the error from this cause averages 4 millimetres. This is very important when it is remembered that the error in a reading at the same distance is usually less than 2 millimetres.

The Author discusses the systematic errors produced in levelling from the compression of the ground by the feet of an observer :—

(*a*) When the legs of the level are oriented by design at angles variously inclined to the line of levelling.

(*b*) When one leg is always placed in the line of route (as recommended by Mr. Bourdaloué).

(*c*) When two legs are placed parallel to the line of route, and the third at right angles to it.

In the first case accidental errors only can occur, varying in size and amount on different lines of sight. In the second,[1] the errors are always positive or always negative, and amount to about 5 millimetres per kilometre—supposing only an error of 1 millimetre in a sight of 100 metres—although this may be avoided by pointing the one leg to the back- and fore-sights alternately. In the third case—and that advocated by the Author—the errors in the back- and fore-sights of each station of the level tend to equalize one another, and never can have the maximum values of the second case, since the feet of the observer are more distant from the legs of the instrument; they are not, however, completely eliminated

[1] The Author recommends that if Bourdaloué's practice be followed, and the line of levels duplicated in the reverse direction, that the one leg should invariably be pointed at the fore-, or else at the back-sight, and then these errors will be neutralized.

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unless the centering of the bubble can be watched at the moment of observation.

This object is secured by the invention under notice; the upper bar of the frame which encloses the bubble-tube is raised from 3 to 4 centimetres above it, to admit of two isosceles rectangular prisms being placed underneath this bar at different heights, in order that the observer may see reflected in them—through an opening in the frame—the two ends of the bubble. These prisms, of which the hypotenusal faces are silvered, or, better still, tinned, are mounted on toothed chairs, acted on by a pinion, and can thus be separated to any distance which the length of the bubble requires. The chairs in their turn slide along a platinum bar, which, with the bubble-tube, is capable of a half-revolution by means of a button on the upper bar of the frame. This invention diminishes the effect of parallax, to which one is liable when centering a bubble, seen, either directly, or by reflection, as in Gravatt's mirror.

Objections having been raised to two points of detail in the original construction, Mr. Klein has now given to the vertical face of the prism furthest from the eye a spherical convex form, in order to correct the excess of distance of the images reflected; and, in order to raise the telescope from the ground and thus almost annul the effects of refraction, he has further made use of two supplementary prisms mounted at the ends of a prismatic sheath, which is hinged to that Y of the level nearest to the eye-piece. The axis of the telescope can thus be set at the height of the observer's eye, while the visual horizontal rays from the prisms are brought down to that level. Another improvement suggested is to engrave simply two index marks on the bubble-tube, instead of more graduations, to avoid errors in centering the bubble.

E. H. C.

Weight Micrometer-Adjustment for Spirit-Levels and Aneroids.

By F. H. Reitz.

(Zeitschrift für Vermessungswesen, vol. xiii., 1884, p. 316.)

After approximately centering the bubble by the foot-screws, the fine adjustment is made by a weight, which in spirit-levels is moved along the telescope-bearings. This weight consists of two cylinders of lead or brass joined by a round bar, and consequently lies symmetrically left and right of the telescope, the total weight (about half a kilogram) being proportional to the dimensions of the instrument concerned. While the instrument is being carried, the weight is either made fast or removed. This invention was patented by the Author in December 1879, though specially for use with his aneroid.

In this aneroid the amount of the air-pressure is read by a fixed

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microscope on a scale, which moves in connection with the vacuum-box, and is graduated to tenth's of millimetres. A slide-bar for a weight is fixed to the arm carrying the scale, and consequently moves with it. The spiral-spring of the aneroid can thus be weighted and a fine motion given to the scale, the amount which the weight has been moved being read off in millimetres and decimals of a millimetre. In moving the weight the cross-hair of the microscope is brought to coincide with the next division on the aneroid scale; for instance, if 750 millimetres be read, and 4·7 on the scale giving the weight-movement after bringing the cross-hair to coincide with 760 millimetres, the barometer reading would be 754·7 millimetres.

E. H. C.

Thermometer Exposure. By H. A. Hazen.

(American Journal of Science, No. 161, vol. xxvii., May 1884, p. 365.)

The exposure which shall give the true air temperature of the locality is discussed under two general heads, viz.:—

1st. The most suitable sites for such exposure.

2nd. The immediate environment of the thermometer.

Under the first a good height above ground, and no interruption of the wind, seem essential. If the thermometer is too near the ground surface, it is affected unduly by damp and fog, and besides, unless exposed on a hill top, the air will become stagnant in hot, nearly calm, weather, and the result vitiated. Experiments made upon an open scaffolding at heights up to 80 feet show that there is little difference in the hotter months in the air temperature at different heights, but that the relative humidity increases in general with approach to the earth's surface.

As regards the second head, an uniform and satisfactory screen for thermometers is indispensable, and one especially that shall at any and all times give an air temperature as little influenced as possible by harmful causes. The following conditions should be realized:—

1st. Perfect access of the air, whose temperature is to be ascertained, to the thermometer under all circumstances.

2nd. The screen should shield from all reflected heat, from direct radiation from the sun by day, to the sky by night, and from radiation from surrounding objects.

3rd. No moisture should reach the thermometer.

The various shelters adopted by different countries are reviewed in relation to the above conditions. The French "Renou" stand seems to check very light winds on the east and west sides, and does not afford sufficient protection against soil or sod radiation. The standard one in Melbourne, Australia, seems to give too much shade in calm weather. The English "Glaisher" stand may give 4° or 5° too high temperature by day, and the same amount

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too low at night by radiation, while the "Stevenson" shelter is too small and close for good results, and in the sun gives too high values; it has been improved upon by Stow. Professor Wild's shelter, in Russia, prevents a free access of air.

The Author reports, with copious Tables, a large series of experiments made in 1883 with three shelters, viz., a "Stow," a Russian, and a so-called "Pattern" (whose main points are good size and free ventilation), and conducted on a roof at Washington 60 feet above ground, and free to air currents save from the south-east. The French "fronde" thermometer with dry and wet bulb was employed as the standard of comparison, as it is specially adapted for experiments upon temperature and hygrometric conditions.

The following conclusions are drawn by the Author:—

1st. Thermometer-shelters when exposed to direct sun heat must be at least 36 inches long.

2nd. The thermometer "fronde," both dry and wet, will, with proper precautions, give the most correct air temperature and relative humidity.

3rd. The interposition of a second louvre seems hardly necessary.

4th. Although in a single-louvred shelter, thermometers may in heavy storms be wetted, yet the bulb is very quickly dried; besides in rainy weather both dry and wet indicate nearly the same temperature.

5th. For obtaining even approximate relative humidity in calm weather single-louvred shelters are necessary, and for the best result an induced air-current is essential, especially in winter in northern climates.

For window-shelters the following suggestions are adduced (from contemporaneous experiments) for places north of 35° lat. N.:—

1st. A free air space of 6 to 12 inches between the shelter on the north side of the building and the wall.

2nd. The simplest form of screen is a wooden box about 11 inches square, having the bottom and side toward the window open; the thermometers, dry and wet, should be placed 5 inches apart near the centre of this screen, with their bulbs projecting below the plane of the lower edge. In summer the window-blinds can be fastened at right angles to the wall of the house as a shield when the sun shines on the north side.

E. H. C.

The Rolling-Planimeter of Conradi of Zürich.

By Professor Franz Lorber.

(Wochenschrift des österreichischen Ingenieur- und Architecten Vereins, 5 July, 1884.)

The advantages claimed for this planimeter are its great accuracy (a series of two thousand and twenty observations with two instruments giving an average error of $\frac{1}{3250}$), which surpasses

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that of the ordinary linear and polar planimeters, especially the latter; and that the extent of surface to be measured may be quite unlimited in one direction, though limited in the other.

It stands upon three points, one of which is the pencil or tracing point, and the other two rollers of equal radius, C. The horizontal graduated arm (length a), at the end of which is the pencil, is attached by a vertical pivot to the frame carrying the spindle on which are the two rollers. On this spindle also is a milled bevelled wheel (radius L), which through another bevelled wheel (radius l), gives motion to a horizontal circular disk, made of hard rubber covered with paper (whose centre is distant b from the central axis). On this disk rolls the measuring roller (radius R), which has a graduated circumference, and whose bearings are in parallel connection with the arm carrying the tracing-point. The number, n, of revolutions of the measuring roller is automatically registered.

The area of the figure traced by the pencil is :—

$$\frac{a\,l\,C}{b\,L}\,2\,R\,n\,\pi.$$

where the letters have the meanings above described.

W. B. W.

On the Constants for Tensile Strength of Different Materials.

By E. Hartig.

(Der Civilingenieur, vol. xxx., cols. 94–110.)

The determination of the quality of materials of construction from the results of tensile tests has given rise to a controversy not yet ended. The proposal of Wöhler, adopted since 1879 by the German Railway Union, to add together the breaking-weight per unit of original area, and the percentage of contraction of area, as a measure of quality, has been opposed by many. To add two numbers of different denominations cannot give a rational result. If the quality is to be judged both with reference to the strength and toughness, then without doubt the work done in breaking the bar per unit of volume or weight is decidedly preferable. In that case the ductility enters the result through the breaking-extension, instead of the contraction of area. In addition to the grounds for preferring the extension given by Tetmajer and others, it may be pointed out that all parts of the test-bar participate in the breaking-extension before the maximum stress is reached, while the contraction is a local phenomenon, developed after the point of maximum stress has been passed.

If a sliver or band of parallel woollen hairs is placed in a self-registering testing-machine, and subjected to an increasing load, there results a diagram like Fig. 1. Whilst the test-piece is

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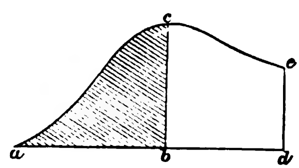
lengthened by $ab = 20$ millimetres the stress increases from 0 to $bc = 1 \cdot 26$ kilogram, and up to that point all parts of the test-piece are similarly affected. For greater elongation the stress diminishes, an elongation of 128 millimetres being required for the complete fracture of the test-piece. Before the stress bc is reached,

FIG. 1.

the stress is not indicated by any contraction or other local phenomenon. After overstepping this value there is a local thinning at the point preparing for fracture. It is clear that ab should be taken for the breaking-extension, and bc for the breaking-stress, for beyond bc the piece can be broken by forces smaller than the maximum. The area abc is the work done in tearing. For the practical estimation of the value of the material the work bcd beyond the limit of maximum stress has no significance.

With a test-piece consisting of fibres more confusedly mixed together, fracture occurs suddenly at some finite stress de, Fig. 2. Here also bc should be taken as the breaking-stress, and ab as the breaking-extension. Such a diagram is also the usual form for weak metals, such as lead, and is obtained also for copper and ductile steel. The ordinate de is of no importance, and depends only on the means by which the stress is applied.

FIG. 2.



Breaking-stress will therefore be defined as the highest stress on the test-piece during the test and breaking-extension, the total (part elastic, part permanent) extension at the moment when the stress is greatest.

Let L be the length of the unloaded test-piece, G its weight. Then $N = L / G$ is its fineness number. If l is the absolute extension ab taken from the diagram, the breaking-extension δ in per cent. of the initial length is

$$\delta = 100 \frac{l}{L}.$$

If P is the breaking-load also taken from the diagram, then

$$R = NP = L \frac{P}{G}$$

may be called the "tearing-length" (Reisslänge).

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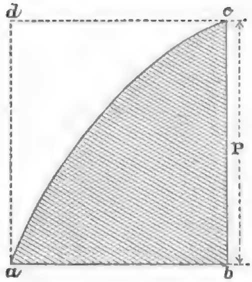
Lastly let η be the ratio of the area $a\,b\,c$ to that of the circumscribed rectangle $a\,b\,c\,d$, which may be called the diagram-efficiency. Then the work done in tearing the test-piece, estimated per gram of its weight is

FIG. 3.



$$A = \eta \frac{\delta}{100} R.$$

The Author then discusses the values of the constants δ, R, η, and A in judging of the comparative value of materials, and gives the following Table of values for a series of very different materials. As the relative values of these numbers only is of importance in considering the Author's views, and as in reducing them it would have been necessary to consider in what English units they could be most conveniently expressed, they have been left in metric units.

—	Breaking-extension in per cent. of Initial Length δ.	Tearing-Length in Kilometres R.	Efficiency of the Diagram η.	Tearing-Work in metre-kilograms for 1 gram of the Material A.
Flax fibre	1·42	6·24	0·400	0·0354
„ yarn (N = 70)	1·59	12·4	0·463	0·0912
Unbleached linen	11·8	8·53	0·304	0·306
Bleached „	10·0	7·60	0·327	0·249
Japanese paper	3·03	6·67	0·658	0·133
Sewing cotton (N = 3·2)	2·98	19·8	0·536	0·318
Cotton rope (50 mm. diam.)	30·0	4·94	0·269	1·083
Manilla (N = 39)	2·44	31·7	0·215	0·166
„ rope (50 mm. diam.)	26·8	8·43	0·395	0·894
Parchment	22·2	4·55	0·683	0·690
Gut (0·9 mm. diam.)	17·6	20·0	0·489	1·72
Whalebone	38·7	8·45	0·801	2·62
Cloth	37·8	0·825	0·52	0·162
Mild steel	25·0	6·41	0·90	1·34
Phosphor bronze (annealed)	55·3	3·99	0·840	1·92
„ „ (hard drawn)	1·42	10·95	0·525	0·082
Raw silk	16·0	33·0	0·713	3·76
Raw rubber	525·0	4·0	0·374	7·83
Vulcanised rubber	362·0	4·32	0·553	8·65

The Author discusses a method of exhibiting graphically the whole of the mechanical properties of a material. He takes the extension (in per cent.) as abscissa, the specific strength (tearing-length) as ordinate, and at each point so found draws a circle, the area of which is proportional to the efficiency of the diagram representing the work done in tearing. The material is more valuable, the greater the abscissa, the greater the ordinate, and the greater the area of the circle.

W. C. U.

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Experiments on the Strength of Timber used in the Eastern Division of the Central Provinces in India.

By G. J. PERRAM, Assoc. M. Inst. C.E.

(Professional Papers on Indian Engineering, January, 1884.)

The woods referred to in this paper are *Pterocarpus marsupium*, used for buildings, bridges, doors, windows, and furniture; *Terminalia tomentosa*, used for the timber-work of public buildings and houses; *Adina cordifolia*, not yet used in public buildings, but in native houses for beams, door-panels, and furniture.

The experiments were made on pieces of well-seasoned wood, 5 feet long, of uniform section, varying from 1 inch $\times$ 1 inch to 2 inches $\times$ 2 inches; the supports were masonry pillars 4 feet apart; the loads were applied at the centre of the span.

The value of the modulus of elasticity was calculated for each deflection observed. It was found that the weight, after the application of which any increase to the load caused a decrease in the value of the modulus of elasticity, varied from 0·40 to 0·91 of the breaking-weight, the average of thirty-seven experiments being 0·672. The modulus of elasticity $= \frac{\text{coefficient of elasticity.}}{432}$ The coefficient of rupture is the breaking-weight in lbs. of a semi-girder loaded at the extremity, of which the length, breadth, and thickness are each 1 inch.

The following Table shows the results of the experiments:—

Botanical Name of Wood.	Vernacular Name of Wood.	Modulus of Elasticity.	Coefficient of Elasticity in lbs. per square inch.	Coefficient of Rupture in lbs.	Coefficient r in Tyndall's "Handbook," and coefficient of transverse strain in Mr. Lala Ganga Rain's Slide Rule = coefficient of rupture.
Tectona grandis .	Teak .	3,212	1,387,584	1,833	611
Pterocarpus marsupium	Beja Sál	3,859	1,667,088	2,364	788
Shorea robusta . .	Sál . .	4,261	1,840,752	2,029	676
Terminalia tomentosa	Saja .	3,887	1,679,184	1,644	548
Adina cordifolia .	Kulmi .	4,037	1,743,984	1,734	578

Tables are given of the details of the experiments, and also formulas, to which the constants are applicable.

W. H. T.

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Destruction of the Tardes Viaduct. By C. Talansier.

(Le Génie Civil, 1884, p. 237.)

This viaduct was intended to carry the railway from Montluçon to Eygurande, across the valley of Tardes, near Evaux, in the department of Creuse, at a height of 300 feet above the river. The design consisted of a pair of lattice girders forming three spans, the two side spans being 228 feet each, and the central 328 feet. The abutments and piers were of masonry, one of the latter being 157, the other 196 feet high. The girders were built up in a valley at one end of the bridge, and had been rolled out over the first and half way across the central span, when a violent storm blew them off their supports into the valley below.

Owing to local circumstances the girder had to be built up in lengths of about 130 feet at a time, and as each length was finished the rolling out of the girder was continued. Owing to the great length and weight of the middle span, a light temporary end-piece nearly 100 feet long, which was afterwards to form part of the first span, was attached to the front of the girder, and a scaffold was built out to a distance of 33 feet from the second pier. In this way the length of completed girder which had to be carried over was reduced from 328 feet to 195 feet.

The rolling-apparatus employed by Messrs. Eiffel & Co. consists of a framework of plate and angle iron resting at its centre upon a pivot, on which it can oscillate: on this framework are two rollers 1 foot 8 inches in diameter. Thanks to the mobility of the system, the two rollers support the girder equally in all positions, and however the thickness of the bottom plates may vary. A ratchet-wheel actuated by a long wooden lever is mounted upon the axle of one of the rollers. When, as in the present case, the weight of the girder is great, the system is modified, as described in the Paper, by the introduction of more rollers.

The length of girder blown over was 430 feet, and its weight about 450 tons, the average height from which it fell was 200 feet, and its horizontal displacement about 50 feet. At the abutment it was broken off from a length of about 200 feet, which was blown violently against the side of the cutting. The masonry of the abutment and pier does not appear to have been injured. No one saw the accident, nor was any noise heard by the workmen, who were living within 200 yards of the place.

Several opinions have been expressed as to the way in which the accident happened. According to one theory the girder was lifted suddenly off the pier and displaced horizontally, so that on settling down again the windward girder struck the middle of the pier and broke, while the other did not touch the pier at all, but dropped over the end. Another hypothesis (which the Author considers the most probable), is that the free end of tho girder began to sway to and fro under the action of the wind, and was by degrees shifted laterally off the supports.

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A calculation is given of the wind-pressure required to shift the girder, which was simply resting upon supports on the pier without any holding-down bolts or other means of resisting lateral pressure, and the Author's conclusion is that a force of from 25 to 30 lbs. per square foot would have been sufficient to produce a slight movement, and from 30 to 40 lbs. per square foot would have shifted the girder off its supports.

The reconstruction of the ironwork has been commenced, and will soon be far enough advanced to allow the rolling out to be resumed.

W. H. T.

Polytetragonal Portable Bridges. By A. Cottrau.

(Il Politecnico, May–June, 1884, p. 339.)

The Author has been studying the subject of portable bridges for years, and this Paper gives a description of his latest design, a specimen of which of 80-feet span was exhibited at the Turin Exhibition. These bridges, whatever be their span, or whatever loads they may be intended to carry, are all constructed by bolting together a greater or less number of three elements, A, B, and C. The element A is a rectangle, 6 feet 2 inches by 4 feet 1 inch, formed of angle-irons about $3\frac{1}{4}$ inches $\times$ $3\frac{1}{4}$ inches $\times$ $\frac{5}{16}$ inch (80 millimetres $\times$ 80 millimetres $\times$ 8 millimetres), with two diagonal angle-irons about $2\frac{1}{4}$ inches $\times$ $2\frac{1}{4}$ inches $\times$ $\frac{3}{16}$ inch (58 millimetres $\times$ 58 millimetres $\times$ 5 millimetres), with gusset-plates at the corners, and at the intersection of the diagonals. The element B is a piece of bar-iron 16 feet 5 inches $\times$ $8\frac{1}{4}$ inches $\times$ $\frac{1}{4}$ inch; and the element C is a cover-plate 3 feet 3 inches $\times$ $8\frac{1}{4}$ inches $\times$ $\frac{1}{4}$ inch. All the elements have bolt- or rivet-holes. The weight of A is 220 lbs.; of B 103 lbs.; of C $2\frac{1}{4}$ lbs.; of a bolt with head and nut $\frac{3}{4}$ lb.; of a long washer $\frac{1}{2}$ lb.; and of a round washer $\frac{1}{4}$ lb. Every element can thus be easily moved and carried about by manual labour.

The bridges can be erected rapidly by unskilled, and still more so by trained, labourers, so that one of 50-feet span can be put up in from fifty to seventy minutes. There are other systems which can perhaps be erected more rapidly, but the Author claims as the special feature of his own that it can be adopted to any span, and to any load, by simply using more or fewer elements. The material is steel, and may in case of necessity be strained up to 10 or 12 tons per square inch, but by using the proper number of elements the strains may be reduced to one-half that.

The elements A are adopted for the webs of the main-girders, and also the cross-girders. They can be combined in various ways according to the strength required. The platforms are made of wooden joists and planking.

The elements can also be formed into piers of considerable height.

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The Paper is illustrated by drawings showing the method of constructing several varieties of bridges, and there is a Table giving the weights, number of pieces, strains, and other particulars of bridges of spans from 25 up to 200 feet. Thus a bridge of 82-feet span to carry a load of 4 cwt. per lineal foot requires 63 A and 84 C elements, and 1528 bolts, and weighs 8 tons, or nearly 2 cwt. per lineal foot. If the bridge were required to carry 14 cwt. per lineal foot, the above figures would be 111 A, 76 B, 40 C, 5370 bolts, weighing 17¾ tons, or nearly 4 cwt. To carry 24 cwt. there would be required 111 A, 92 B, 40 C, 5520 bolts, and the weight would be 18½ tons, or 4·1 cwt. per lineal foot.

W. H. T.

Proposed Railway-Bridge across the Straits of Messina.

(Giornale del Genio civile, May 1884, p. 233.)

This design is put forward by the directors of the Novara-Pino and the Genoa-Acqui-Asti Railways. The bridge is to have three steel arches of 3,280 feet from centre to centre of the piers and two half arches of 1,640 feet. The depth of the straits where the bridge crosses is 360 feet. The piers are to be built of granite in cement, founded on masses of granite thrown down into the sea, and brought up to within 65 feet of the surface. The piers are to be 33 feet high from the water to the springing-level, and above this they are to be built of immense blocks of granite to a further height of 62 feet for the arches to abut against. The width of the piers is to be 236 feet, the clear span of the arches 3,083 feet, and their versed sine 328 feet. The thickness of the arch at the springing is 65 feet, which is reduced towards the crown. The road is carried on a longitudinal girder 10 feet in depth, connected with the arch by lattice-bracing.

The width of the bridge is 65 feet at the centre, widened out to 197 feet at the springing, to give lateral resistance to the structure and to enable it to withstand wind-pressure. The arch is to be erected without scaffolding or centres. Above each pier a temporary structure is to be erected similar to the lattice-work between the horizontal girder and the arch but in an inverted position, and forming with the latter a pair of cantilevers. The operation of erecting the arch is to be carried out thus: First, the arrangement above described is to be put up, consisting of the permanent lattice-work and the temporary inverted lattice, forming a cantilever on each side of the pier 690 feet in length. Next a length of 525 feet of the main arch is to be erected on each side of the pier. The erection is then to be extended a further length of 260 feet on each side. An additional length of 130 feet is then added, being as before supported by the longitudinal girder and lattice-work, which are kept in advance of the arch. Similar processes are repeated till a length of 1,230 feet on each side of the pier is in position, leaving a length of 410 feet on each side to complete the

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two half arches, or 820 feet in each arch; but this, being the lightest part of the structure, can be put together on the part already erected, and then rolled out and lowered into position.

W. H. T.

Shingle on East Coasts of New Zealand.
By W. W. Culcheth, M. Inst. C.E.

(Proceedings of the Royal Society of Victoria, May 8, 1884.)

Two main lines of beach are described, namely, that in the North Island at Hawke's Bay, which commences 11 miles south of Napier, and extends 10 miles north of that town, or 21 miles in all. 30 miles further north-east, a finer beach of sand and shingle extends along the northern margin of the bay. The Author asserts that "the chief source of supply of the shingle is the river Tuki Tuki," which is situate at the extreme southern end of the bay, with a shifting bar. The prevalent seas are from south-east, but north-east seas at times cause great changes in the shingle. South of Napier, the narrow belt of shingle forms the connecting peninsula between the mainland and the town, formerly known as Scinde Island. Northward of this, seas from north-east are described as the motors.

At the entrance to Napier harbour, 1¼ mile west of the bluff of Scinde Island, piers were run out a few years back, and the shingle advanced with the eastern one during construction, but at last the pier appeared to outstrip its advance, at least as defined by high water, but at low water it spread further out, but ultimately "advanced right up to the mole within the space of two days." The same result is predicted for Timaru. At both these moles, in bad weather, the shingle is washed over their crests 6 feet above high water. A large accumulation has formed to the westward of Napier, gradually trending north, and enclosing Ahuriri Lake, "Manga Nui-o-Rotu," a lagoon 5 miles long by 2 miles broad, the spit joining the mainland 4 miles north of Napier; and 7 miles further on, 11 miles north of Napier, the main beach is bounded by the cliff Whakaari, which projects at right angles to the general trend, forming a point projecting about a mile in an east-south-east direction.

The "Ninety Mile Beach" in the South or Middle Island extends from Banks' Peninsula in a south-west direction to Timaru. The seaboard is described in the Admiralty charts as a low level country without trees, fronted with cliffs 25 to 40 feet high, and a broad shingle beach. It encloses at its north end a lagoon—Lake Ellesmere, or "Waihora" lake, 10 miles by 7 miles. The main beach is intersected by four large rivers, the mouths of which are always open, and two smaller ones. The beach really extends 50 miles further south (to Oamaru), or 140 miles in all. The principal source of supply of this immense accumulation of sea-drift is asserted by the Author to be the river "Waitaki,"

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and this river is only 15 miles north of the extreme southern end of the main shingle belt. "Cliffs from 30 to 40 feet high are marked on each side of the mouth of this river. Some of the shingle is said to come from these cliffs." The shingle on the beach at Oamaru is evidently driven there when the wind is north of east. At Timaru a breakwater is being built, and shingle is thrown up to the summit in gales (6 feet above high water), and over it, and has to be cleared away by hand, and shingle is accumulating seaward of it. "North-easterly weather must continue to drive shingle down the coast from the river Waitaki"; but south-east winds are said to prevail on this coast.

The Timaru breakwater now being constructed has given rise to much controversy from its being situate in the middle of a mole of travelling shingle. A length of 400 feet to 500 feet was first proposed, but fears prevailing that the shingle would get round the extremity, its length was extended to 1,400 feet. It is found that "the shingle would be carried over the work were it not cleared away by manual labour." The erosion of the coast to leeward of the breakwater is described, and the artificial works of defence entailed, and "it was at one time even proposed that the breakwater should be cut through to allow of shingle passing as before." Of the rivers intersecting the main line of beach between Banks' Peninsula and Timaru, the Author says conjecturally "that he does not know whether these rivers bring down further supplies of shingle or not; probably they do, for the whole of this part of the country is said to have a substratum of shingle." The neck of loose shingle enclosing "Waihora" or Ellesmere Lake is nearly a mile in width at places, and "at the extreme end the shingle has been thrown up against a cliff to a height of 30 feet above sea-level." This abnormal height is characteristic of these formations where checked by a jutting promontory such as Banks' Peninsula. The largest pebbles in these shingle moles are seldom more than about 6 inches by 4 or 5 inches by 3 inches. Some one-third larger each way were found near the mouth of the river Waitaki, but the average size is much less than the above dimensions, and in places near Napier it is "little more than that of coarse sand." Of the larger pebbles the Author says: "These stones have, evidently, from their rounded appearance, before being thrown on to the beach, been subjected to the action of water in a former age, and are now found embedded in earth. They are chiefly derived from the rivers already mentioned, down which they are carried during freshets."

Of the Canterbury rivers it is said, "where the rocks are not actually broken up, they are so easily disintegrated that every small stream forms a large fan of shingle when it reaches the valley. During floods the streams cut deep gulches through these fans, carrying the shingle away into the main river." But this is followed by this sentence of reservation:—"The cliffs along the coast, particularly on the South Island, are said also to furnish a large portion of the supply of shingle." At the mouths of the

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rivers, "the stones and pebbles are thrown in a large mass on the shore, almost, sometimes quite, blocking up the mouth, while the earth is carried away into the sea."

The material of the beaches is described as mostly a "bluish-grey stone, usually described as clay slate. Most of the stones from both coasts show, when fractured, a silicious composition. Some stones frequently found near Napier, are evidently from a sandstone formation," and the pebbles are described as "flattened ovoids." Of the motor producing these results, the Author says: "The wave-action, then, is the chief agent concerned in the transport of the shingle along the Ninety-Mile Beach, and near Napier."

The action of waves on a beach is investigated, and how the shingle is caused to travel along the shore, and the wave-action under varying conditions described, as also the resultant disposition of the materials, and the reasons are examined why "large shingle is often not found below the water-line." As regards the action on the bed of the sea near the shore, the Author says: "With a heavy sea and a gale blowing on shore, large stones might easily be transported from a considerable depth in the bed to the beach."

The difference of opinion and the uncertainty as to the depth at which this action ceases are referred to, and attention is drawn to the fact that the off-shore belt of discoloured water from suspension of fine material is wider in fine than in heavy weather. "In fine and calm weather there would be less to obstruct the motion seawards of particles of matter held in suspension near the surface." Of the relation between wave-action and the slope of a beach Mr. Culcheth says, "Not only boulders and shingle, but sand, merely, is sufficient, under certain conditions, to withstand the force of the waves, even in the heaviest sea." The flattening of the slope until it is able to withstand wave-action is described.

The slopes when the beach is in a normal state are given as 1 in 10, decreasing where the material is finer to 1 in 15 or thereabouts, but when the shingle is moving rapidly forward a portion of the slope might be even 1 in 4. The Author, however, says this is only temporary, and he thinks "more definite information regarding the normal slope of shingle is required." A summary of wave-action is given as stirring up material, and carrying a portion up the slope. The return waves wash some material down, the force increasing until checked by the incoming wave, the meeting of such waves causes deposition. Oblique waves as regards the shore line cause a leeward motion or travel of the shingle. "The bed of the sea near the shore is in a state of continued oscillation, unless when the sea is too quiet to move the material." With a steep shore wave-action flattens the slope, and wave-force is reduced. With a flat shore, material thrown up will probably remain, and the slope be gradually increased, and wave-power proportionately increased. Of the movement of shingle along the shore he says: "Shingle will not only move at varying rates at different times, but on many, perhaps most, parts of the coast it will move sometimes in one direction and sometimes in the opposite direction, though, as a

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rule, there is decidedly a greater movement one way than the other."

Of the varying section and amount of shingle on different frontages Mr. Culcheth puts his view thus: "Another point not to be overlooked is that, although the quantity of shingle in motion may be constant, it may, nevertheless, appear to be different at different points. Where the trend of the coast favours a rapid movement one way, the width of the beach is likely to be less than when the motion is less constantly in one direction, or the waves strike with less force. In other words, the sectional area would be in inverse ratio to the mean velocity."

Of the disappearance of shingle at certain points, although the supply be continuous, he suggests: "A current flowing round a point, or a current sweeping round a bay, may remove the finer material forming the base of the shingle, and may thus increase the slope."

He believes that under these circumstances some shingle may be moved below low water, or it may disappear at the mouth of a tidal river. Also, in the wearing down process, "the finer particles are carried under the water-line, while the shingle remains on the beach." He cites the disappearance of shingle, or its dying out into a sand slope, and describes the way in which shingle may travel forward abreast of a sudden recession of the shore-line, and thus enclose lagoons, such as are characteristic of these New Zealand coasts; and he examines and describes the action of the travelling shingle in deflecting the outfalls of certain rivers. Many of these New Zealand rivers appear subject to heavy floods for a series of years, and then the reverse is the case for another series. When the floods are less for a few years in succession, the shingle will be less frequently broken through, and the river mouth more deflected. The Paper concludes with some remarks on the movement of shingle below water, illustrated by the operations at Napier harbour, respecting which the Author says, "all attempts to keep it clear have, except when the shingle was trapped for a time behind the east mole, failed to secure for any length of time a greater depth than 8 or 9 feet at low water." It appears that cavities in the bottom, north-west of the bluff in Ahuriri Road, 15 feet deep, are emptied of shingle with easterly gales, and the shingle over a very rough bottom travels round the Bluff to the depth of 18 feet below water. Doubt is expressed whether this be due to wave-action or tidal-currents.

In his summarised remarks he attributes the leeward motion to the oblique impact of the waves on the shore. He concludes that shingle of any considerable size is rarely moved below water by wave-action; that there is a certain slope peculiar to each size of shingle (its normal slope); that the largest pebbles collect near the water-line, decreasing in size upwards and downwards, and very rapidly in the last direction. That the slope will be steepest between high-water and low-water; above high-water the beach will assume a convex profile, below low-water a concave profile. With a slope flatter than the normal the largest shingle should be

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at or above high-water. With the slope steeper than the normal, "the large shingle should be looked for near low-water level."

Uniformity of shingle occurs with uniformity of coast outline; with an irregular coast outline and jutting points, "shingle will sometimes accumulate, and at other times the excess will be removed. In places the beach may be almost, or entirely, denuded of shingle. A high beach will have a steeper slope, and will consequently be formed of larger shingle, than a low beach."

Shingle is lost from the beach by being carried below the water-line by streams, and by the finer particles being separated and drawn under water. When abruptly arrested, and the supply "is too great to permit of the whole being reduced to sand, the shingle accumulates." If this occurs against a cliff, or where waves break with force, a high bank results, but if where ordinary wave-action alone takes place, "the shingle is arranged in successive ridges one in front of the other." With travelling shingle, a bar will form across the entrance to a river or lagoon, with probably not more than 8 or 10 feet at low water; also from any point where the trend of the coast suddenly changes, or from the end of any jetty or similar projection. In other situations shingle may travel at considerable depths. "It has been observed to do so, to a limited extent, at as great depths as 6 and 8 fathoms. But whether shingle is thrown up again from such depths on to the beach is doubtful." The Author however, says, "These propositions need to be confirmed by further information before they can be considered of general application."

The following extract from the appendices may fitly terminate this abstract: "A few points to be noticed when observing the movements of shingle. Besides the main features of the locality and the state of the weather at the time, it is important to ascertain what the weather for a few days previously has been, and the corresponding action on the beach. Not only the direction of the wind but the direction of the waves with reference to the shore should be noted. The approximate height of the waves, the number of waves per minute, and whether the water falling from the crest of the waves, as they break, strikes directly on the beach or on a cushion of water." The section or profile of the beach, any information respecting material and slope below the water-line, when obtainable, over as great a length of beach as possible, noting whether there is more or less shingle than usual.

J. B. R.

The Employment of Double Floats for Measuring Velocities in large Streams. By H. Bazin.

(Annales des Ponts et Chaussées, 6th series, vol. vii., p. 554.)

A comparison is made in this article of recent important and careful observations of the velocities of flow in large streams, with the object of showing that the discrepancies between the

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results are merely apparent and due to the nature of the instruments, and with the view of indicating the corrections necessary in the results of observations with double floats.

The current-meter, with an electric recorder, is the most reliable instrument; but if the experiments are conducted in a deep rapid current, the apparatus must be costly. The double-float provides a simple and ready method, but it is liable to errors, which increase so much with the depth and velocity of the current, as to render the results useless in some cases. The conditions necessary to ensure perfect accuracy are, that the two floats should travel with the same speed as the layer of water surrounding the bottom float, and that this float should retain its original position in the stream. Unfortunately, the surface float and cord modify the motion of the lower float, and the lower float is raised by the eddies of a rapid current; and when the velocity exceeds 5 feet a second no reliance can be placed on the position of the bottom float.

The experiments compared are those of Mr. Ellis on the Connecticut, 1874, with a current-meter and floats; those of Major Allan Cunningham on the Ganges Canal, in 1874–79, with floats; those of Mr. Harlacher on the Elbe and the Danube, in 1876–79, with a current-meter; those of Messrs. Nazzani and Zucchelli on the Tiber, in 1880–81, with a current-meter and floats; and those of Mr. Gordon on the Irrawaddi, in 1882, with a current-meter and floats. Numerous Tables are given of the results of each series of experiments.

In Mr. Ellis's experiments the velocity of the stream was small, the greatest velocity hardly exceeding $3\frac{1}{4}$ feet per second; whilst the area of surface of the top float and connecting cord was only one-sixth of that of the bottom float, so that the bottom float was not liable to be affected by eddies, and could be little influenced by the motion of the cord and top float. Accordingly, as might be anticipated, the results of the two methods of observation fairly coincide. The surface-velocities obtained by the current-meter are evidently too low, owing doubtless, either to the ripples over the surface of the water, or the eddies produced by the boat from which the current-meter experiments were taken. On the other hand, the velocities given by the double float are manifestly too great for the lower depths. As in these experiments the velocities are very low, the slightest errors modify the results; so that the parabola, indicating the decrease in velocity in a vertical plane in a line with the current, cannot be traced with precision. The proportion of the surfaces of the upper float and connecting cord to the surface of the lower float was a little over one-half in Major Cunningham's experiments; and the velocity of the current was greater than in Mr. Ellis's observations. The increased relative proportion of the surface of the upper float and cord, and the increase in velocity, together with the fact that Mr. Ellis's observations were conducted on a river and the others on a uniform canal, materially reduce the proportion between the maximum and mean velocities, and the

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parameter of the parabola marking the decrease in velocity. In Mr. Harlacher's experiments the value of the relation between the maximum and mean velocities is larger than that obtained by Major Cunningham, the maximum velocity of the streams being also larger. The maximum velocity was almost always at the surface in the Elbe observations, taken at Tetschen; and the parameter reached, on the average, the value of 0·61, which is higher than in the previous observations. The upper float and cord in Mr. Zucchelli's observations on the Tiber exposed a surface of nearly one-fifth of that of the lower float, in depths ranging between 20 and 23 feet, and about two-fifths when the river had risen so as to attain depths of 33 to 50 feet. In every case, in these experiments, the relation of the velocities observed at the various points to the mean velocity approximated to unity, the values diminishing with the height of the river for points near the surface, but increasing for points near the bottom. Comparing the above results with those on the Mississippi and the Irrawaddi, it appears that in these rivers the relation of velocity to mean velocity, and the parameter also, decrease in proportion as the depth increases, but are smaller, especially on the Mississippi. This progressive decrease is due to the influence of the surface of the connecting-cord, which increases with the depth, and ends by completely vitiating the results in the great depths of 70 feet and 110 feet reached by the Irrawaddi and Mississippi respectively; for the relation of the surfaces of the upper float and cord to the surfaces of the bottom float, whose maximum on the Tiber is two-fifths, attains four-fifths on the Irrawaddi, and unity on the Mississippi. The results obtained by Mr. Nazzani with current-meters on the Tiber do not coincide with those from the double floats, as the relation of the velocities and the parameter increase in the experiments with the current-meter and decrease with the floats. In Mr. Gordon's recent comparative experiments on the Irrawaddi with current-meters and floats, the results obtained are very different. The proportion between the velocities observed at the various points and the maximum velocity decreases with the depth in both cases, but the decrease is much more marked in the results obtained by the current-meter; and in some instances the results of the two methods at the greatest depths differ by one-third of the maximum velocity. Mr. Gordon's observations prove beyond doubt that the employment of double-floats for measuring velocities, at considerable depths in rapid currents, leads to serious errors. On the other hand these experiments also indicate, as in the previous results, that the current-meter furnishes too low velocities at the surface.

Comparing the results of the preceding experiments, it appears that the relation between the velocities varies but little in the observations with current-meters, being always between 1·14 and 1·20; whilst this relation in the case of floats is lower and more variable, ranging between 1·02 and 1·14. The influence of the cord connecting the two floats is more marked as the depth

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and velocity increase. It is evident that gaugings conducted with double-floats furnish too large values for the discharge, and should be revised; whilst the unexpected rise of the proportion between the maximum and mean velocity on several large rivers necessarily implies a greater impediment to the flow, so that the formula ordinarily employed would also give too large discharges. The old formulas of Prony, Eytelwein, and others, were based upon a limited number of observations, representing simply the steady flow of a moderate sized river, for which the formula $v = 50 \sqrt{R I}$ was generally adequate. The observations on the Seine and the Saône show that for these gently flowing rivers the value of the coefficient c may be made 50, as in the above formula. Mr. Graëff has found $c = 36$ to be suitable for the tributaries of the Upper Seine. It appears that for the Rhine at Basel, in spite of the size of the river, the value of c is as low as 38, owing to roughness of the bed, which is covered with large shingle. Even very large rivers are affected by the irregularities of their bed, so that for the Danube at Vienna $c = 42$. In the Irrawaddi also, the value of c is less than 50. The Mississippi experiments give anomalous results, and very high values for c where the inclination is very small; but taking only the most reliable results, the mean value of c would be 70. These observations, however, like those on the Irrawaddi require correction, which would reduce the value of c below 60. Observations with current-meters are needed on the very large rivers, from which a suitable coefficient might be deduced, so that serious errors in the calculation of their discharges may be avoided, for which at present there are not sufficiently accurate data.

L. V. H.

An Automotive Tug. By R. Perrin.

(Association Française pour l'Avancement des Sciences, Compte-rendu, 1883, pp. 243–252.)

That a current of water can be ascended without the employment of any motive power other than that of the stream itself has long been known to be theoretically possible. Suppose, for instance, that in one of the tug-boats which move by hauling on a submerged chain, the driving-pulley, instead of being actuated by a steam-engine, is driven by paddle-wheels, on which the stream impinges; then, if there is a sufficient ratio between the leverage at which the fluid pressure acts, and that at which the resistance opposed to the ascending motion of the vessel acts, the vessel will be propelled up stream. Let m be the ratio of the leverage just described, or, more strictly, let m be the ratio, depending on the mode of connection employed, of the velocity of the centre of pressure of the paddle-floats relatively to the vessel, and the velocity at which the chain winds on the driving-pulley. Let v

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be the velocity of the stream, and w the speed of the boat, then it can be shown that—

$$w = v \frac{(m-1)\,K\,s - S}{(m-1)^2\,K\,s + S},$$

where s is the area of the vertical paddle-floats, S the midship section of the boat, and K a coefficient depending on the form of the boat. The practical realization, however, of an automotive tug presents great difficulties. The floats must have a large area, but their length is limited by the dimensions of the bridges, &c., the vessel must pass, and by considerations of transverse stability. The weight of the paddle-wheels and other conditions limit the width (vertically) of the floats. Still, if an automotive could be realized, by which a stream could be ascended at a speed not too much reduced, it would no doubt be applied in many cases, on torrential rivers for instance, such as the Rhone, where the up-stream navigation is laborious. The Author then describes an experimental vessel constructed to test the practicability of these ideas. The vessel was 9 metres (30 feet) in length, and 1·1 metre (3·6 feet) in draught. It had two paddle-wheels and a driving-pulley on the same shaft, so that the driving force acted directly without intermediate gearing. It was important to be able to vary the ratio designated by m. To attain this, the driving-pulley was formed of a cast-iron centre, and six pairs of arms. The two arms of each pair were connected by a bolt, which could be fixed at will in one of three series of holes. These bolts formed the angles of a hexagonal surface, on which the chain rolled, and according to the series of holes employed this surface was nearly equivalent to that of pulleys 1·6 metre, 1·2 metre, and 0·9 metre in diameter ($5\frac{1}{4}$ feet, 4 feet, and 3 feet). Suppressing the bolts, the chain would roll on the nave of the wheel, equivalent to a pulley of 0·6 metre diameter (2 feet). The ratio m could then be made 1·5, 2, $2\frac{2}{3}$, or 4. The bolts were furnished with three grooves, so that the chain could be taken three times round the drum, and there was a tightening pulley also with three grooves. The chain came into the vessel over a guide-pulley, and passed out astern over a second guide-pulley. The paddle-wheels carried each twelve floats, 2 metres (6·56 feet) long, and 0·8 metre (2·6 feet) wide. The floats were partly hinged at their outer ends, so as to fall down when rising out of the stream, and obviate the tendency to lift the water. To give greater stability, two small lateral hulls are added outside the paddle-wheels, each 13 feet long. To stop the boat, or to make it move down stream, or to cause it to turn to either side, vertical sluices were placed in front of the paddle-wheels. These consisted of three vertical iron plates, sliding in grooves like chimney dampers. By lowering them the action of the stream on the paddles is prevented. By lowering them unequally a dissymmetry is produced in the resistance of the boat analogous to that of a powerful rudder. The

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Author then describes a series of experiments with this boat on the Seine. With a current of 1·2 metre (4 feet) per second, the chain taken twice over the driving-pulley, 0·9 metre (3 feet) diameter, the boat carrying twelve persons, ascended the stream at 9·96 metres (33 feet) per minute, calculated from the speed of the driving-pulley. The adhesion of the chain was, however, insufficient, and the real speed was less. With three turns of the chain on the pulley the speed was 8·52 metres (28 feet) per minute. With a current speed of 1·1 metre (3·6 feet) per second, the chain having three turns on a pulley of 0·9 metre (3 feet) diameter, the boat ascended the stream at 8·04 metres (26·4 feet) per minute. A small tug-boat was then moored to the automotive tug, and this was towed up stream at 6 metres (19·7 feet) per minute. The Author then discusses these results, which show that the speed of the boat was about one-eighth that of the current.

W. C. U.

On some of the Machines employed in the Excavations at Hoek van Holland. By W. F. Leemans.

(Tijdschrift van het Koninklijk Instituut van Ingenieurs, 1883–1884, p. 263.)

On the works for enlarging the entrance to the new fairway between the North Sea and Rotterdam, at Hoek van Holland, three types of excavating machines are principally used: the Couvreux excavator, working above water-level; the Priestman elevator, and the suction-dredger, for excavations under water.

The Author first reviews excavating plant on the Clamshell system; he gives some of the instances in which it was employed on other works, and mentions the use of a Priestman elevator at the Hoek van Holland in 1880.

Before this time suction-dredgers were adopted, viz., the Adam I., on the Stutton system, as used on the Ymuiden Harbour works; the Geopotes I., on the Bazin system, and the Adam II., being an improvement on both. In 1878 and 1879, 700,000 cubic metres were excavated by these means.

These suction-dredgers, however, could not be employed when the wave-height exceeded 0·5 metre, and while the construction of an improved suction-dredger was in hand, the contractors, Messrs. Volker and Bos, were induced to make a trial with a Priestman dredger. A specification was obtained from the manufacturers for a self-loading and self-propelling dredger on this system.

It was, however, considered that the stability of the proposed dredger would not be sufficient in a seaway, and a machine of this type was only used for dry excavation. The results obtained were below those from the Couvreux excavators. With these latter engines, 2,122,700 cubic metres were moved during the years 1882–1884.

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The Author gives a detailed statement of the work performed by each of the three machines, and compares the cost of work done by the Priestman and the Couvreux systems.

For sub-aqueous dredging the suction system was principally used. The dredger Adam II. is fitted with a single centrifugal pump, and one suction-tube going down through a well in the ship's centre-line. The hull is 100 feet long, 25 feet beam; draws, when filled, 10 feet, and is a self-propelling hopper-barge, with a 35 nominal HP. engine placed aft, which either drives the centrifugal pump or the twin screws. In forty-five minutes, 139 cubic metres of sand can be loaded. But conveying the material to a distance of 5½ kilometres; measuring the contents; dropping, then returning to the spot and anchoring, requires about two hours; so that in reality the 139 cubic metres are removed in two and three-quarter hours. During the year 1879, this dredger furnished work to a total amount of 96,222 cubic metres, during one hundred and sixty-five days, or an average of 580 cubic metres per day.

Besides the above-mentioned dredger Adam II., five others of a similar type were at work during the years 1882 and 1883. The suction-tubes of these are, however, fitted outside the hull instead of through a well, which is found to be an improvement, being less liable to breakage and easier to repair.

The contract price paid during the years 1877–1880 averaged 0·57½ Dutch florin per cubic metre, and during the period 1882–1884, 0·39½ Dutch florin per cubic metre, or 11½*d.* and 8*d.* per cubic metre respectively.

The Paper also contains information as to the performance of dredgers on other works, as at Ymuiden, Calais, Dunkirk and Boulogne, and a statement showing the improvement effected in the fairway through the Hoek by the operations during the years 1881, 1882, and 1883. Several plans and drawings accompany the Paper.

H. S.

Dredging Appliances at the Panama Canal-Works.

(Le Génie Civil, vol. v., p. 17, 1 plate and 4 woodcuts.)

The Panama Canal involves two distinct kinds of dredging, namely deepening the approaches in the sea, and excavating the canal inland. The dredgers employed for the sea-works have been previously described[1]. The dredgers for the inland works are those described in the present article; and the dredging operations must be separated into two successive stages for the efficient conduct of the work. During the first stage it is important to form a trench with a small depth of water penetrating as far as possible inland, both to facilitate the carrying on of the works,

[1] "Le Génie Civil," Vol. iv., No. 13.

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and also to afford evidence of the progress of the undertaking. Four dredgers have been constructed by the contractors, Messrs. Couvreux and Hersent for this purpose, reserving the construction of more powerful machines for a later stage of the works. These dredgers can either deposit the dredged material into barges, or discharge it on to the banks through a long shoot. They have all been constructed of the same type, and differ only in the form of the discharging shoot, which has been given a rectangular section in two of the dredgers, and a circular section in the other two to facilitate their conversion into long-shoot dredgers. Each dredger consists of an iron barge, 108 feet long, 21⅓ feet wide, 8¼ feet deep, and drawing about 3¼ feet of water; its central ladder of buckets can be raised and can work in advance of the dredger, as the well is open to the end. The upper drum, supported on the central iron staging, has its axle 26¼ feet above the water-level; and the shoots fixed to the staging have an inclination of 33°, their upper ends being 18½ feet above the waterline; the diameter of the circular shoots is 3¼ feet. The dredger is provided with a compound-engine of 60 HP. which can work up to 80 HP. The cost of one of these dredgers was about £10,000. When the dredger is working near the sea, or near a place where material may be deposited in the water, the dredged material is discharged into iron hopper-barges. These barges are 98 feet long, 19 feet wide, and 7½ feet deep in the centre; their draught is 1⅔ foot when empty, and 6⅓ feet when loaded. There are two wells in each barge separated and surrounded by watertight compartments. The wells have a total capacity of 10 cubic yards. Each well is divided into three transverse compartments, and each compartment is closed by a double flap-door. They require for being emptied a depth of over 6½ feet, in order that the doors may open; and it would be advantageous to have barges with lateral doors for discharging in shallow places. There are also ordinary iron barges of similar dimensions, with watertight compartments at each end and along the sides of the well to ensure flotation when fully loaded; they can carry 156 cubic yards. The long shoot is used for discharging the dredged material direct on to the banks at the side, whenever the dredger is working near enough to the sides and the banks are low enough. This latter condition is not fulfilled for any long distance continuously in the irregular and rugged land forming the isthmus, and therefore the contractors have designed the dredgers so that the long shoot may be easily substituted for an ordinary shoot, and *vice versâ*, to suit the changing conditions of the work. Besides adjusting the long shoot to the dredger, it is also necessary to bring alongside the vessel carrying the shear-legs for supporting the shoot on the side on which the shoot stretches, and the vessel carrying the pumping-machinery on the opposite side. The long shoot is readily connected with the circular shoot by fastening a conical piece to the end of the latter, for reducing the diameter from 3¼ feet to 1½ foot, the diameter of the long shoot, but in this case the long shoot is

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lowered to the extent of the considerable inclination of the circular shoot. In the case of the rectangular shoot, a special piece is substituted at the summit without taking down the shoot. Before the long shoot is erected, the two vessels at the sides are fastened to the dredger by bolts, their exact level being adjusted by ballast. The shear-legs are then erected on their vessel, and the long shoot is put together in lengths of 16½ feet, and in proportion as the weight of the shoot comes on the vessel its ballast is removed. The ballast is left in the other vessel so that it may act as a regulating counterpoise when the long shoot is weighted with the dredged material. The long shoot has eight lengths, giving it a total length of 131 feet; it is made of steel-plates, and weighs about 2¼ tons when empty. Each length is supported by a steel-wire cable passing over the top of the shear-legs. The shoot has an inclination of 1 in 20, and its end is 11⅓ feet above the water-level when attached to a dredger with a rectangular shoot, and only 9¾ feet high when connected with one of the circular shoots. The dredged material is carried along the shoot by means of a stream of water from the pump which can discharge 15,900 cubic feet of water per hour at a height of 18 feet. The mixture which is discharged through the shoot consists of about three-fifths water and two-fifths of solid material, and all substances not approximating too close to the size of the shoot are readily carried along. When the shoot becomes choked with too large material, or the roots of trees or other débris, it fills up and becomes too heavy, and the shoot touching the bank is liable to break. Formerly, on the Suez Canal, the shoot was counterpoised by a suspended weight, and on one occasion when the shoot was broken, the counterpoise being unbalanced overturned the dredger. Since then a floating counterpoise has been substituted, which has removed this source of danger, and prevents any serious fracture of the shoot from the above cause. All such accidents might apparently be avoided by making the shoot very slightly conical by enlarging its diameter 8 inches at the extremity. The floating discharging dredger consists of two iron barges, 89 feet long, 15 feet wide, and 8¼ feet deep, placed 21⅓ feet apart, so that one of the barges loaded with material can come between them, and connected together above by a staging of iron uprights and girders, which supports a ladder of buckets between the two barges. The engine for working the dredger is placed in one barge, and the other barge holds the pump which supplies the water for discharging the material lifted by the bucket, and introduced into the long shoot connected with the machine. There are four of these dredgers on the works. The excavating dredgers, filling fifteen buckets with a capacity of 11¼ cubic feet per minute, should theoretically excavate 3,770 cubic yards in a day of ten hours; and the discharging dredgers, filling thirty buckets per minute of half the size, should perform the same amount of work. In reality the discharging dredger does much more work than the excavating dredger, for it raises loose material, and has not to be constantly

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canal. Owing to the disproportion between the revenue and the working costs, which are less than 11 per cent. of the former, (10·46 per cent. in 1882), the latter have been plotted to a much larger scale than the former, as the annual variations would otherwise have been almost inappreciable in the diagram.

F. R. C.

Cost of Carriage by Rail and Canal. By H. Von Borries.

(Zeitschrift des Vereines deutscher Ingenieure, 1884, p. 298.)

A canal from the Westphalian coal district to Emden being projected, the Author compares the cost of carriage upon canals and on a single-line mineral railway with few stations and a small staff. Assuming eight trains of sixty loaded wagons per day to the port, of which twelve are returned loaded, and a cost of £6,000 per kilometre for building the line, as actually incurred for similar lines in the district, he calculates the cost per train-kilometre as follows:—

	d.
Repairs and renewals of locomotives	1·20
Fuel	2·40
Cleaning, oil, &c.	0·54
Repairs and renewal of wagons	2·88
Lighting and heating of guard's van	0·02
Drivers' wages, including mileage	1·41
Guards and brakesmen's wages, including mileage	2·46
Inspection, &c., of rolling stock	0·13
Station-service	3·12
Permanent-way, repairs, and signalmen	4·32
General management	1·56
Interest on capital account for line, locomotives, and wagons, at 4 per cent.	14·52
Total	34·56*d.*

or $\frac{34 \cdot 56}{3 \cdot 60} = 0 \cdot 096d.$ per ton-kilometre $= 0 \cdot 16d.$ per ton-mile.

The carriage on the Elbe canals costs 0·35*d.* per ton-mile, and on the canal from the Belgian coalfields to Paris 0·29*d.* in spring and 0·34*d.* in autumn 1883, without paying interest. Estimating the cost of the Ems canal at £16,000 per mile, and adding 4 per cent. of this, the carriage on the canal would cost about 0·4*d.* per ton-mile. The items in the above estimate are calculated from the actual returns of similar German lines.

C. B.

The useful Effect of Horses in Omnibus Traction.

By E. Lavallard.

(Rapport[1] de la Compagnie générale des Omnibus de Paris, 1884, p. 20.)

The Paris Omnibus Company have on an average 13,679 horses in daily work, classified according to their service as follows:—

[1] The original is in the Library of the Inst. C.E.

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9,377	Road	omnibus service,	with	15·1	horses	per vehicle.
3,541	Tramway	„	„	13·73	„	„
586	Railway	„	„	14·19	„	„
175	Versailles.					

Out of 15·1 horses per omnibus, 12·24 are actually in work; the remainder, including reliefs, sick animals, and those in accessory task work.

The average distance travelled daily by each horse in service is:—

In road omnibuses	16,034 metres.
tramways	16,362 „
railways	17,996 „

In a discussion of the reasons for the small distance travelled, which can only be with difficulty raised to 18 or 20 kilometres per day, the Author states, as the result of dynamometrical experiments carried on since 1878, that the average work is 82 kilograms per second per tramway horse, and 95 kilograms per omnibus horse, the average speed being 3 metres in the first and 2·50 metres in the second case. Each horse, therefore, during the time that it is actually drawing does work to the extent of $\frac{11}{10}$ HP. in an omnibus, and $\frac{13}{10}$ HP. in a tram-car; such an effort cannot, however, be long continued. The average time of each tramway journey is 46 minutes, and that of an omnibus 48 minutes. In the former case the minimum is 32 minutes, the maximum 70 minutes, and in the latter the minimum 26 minutes, and the maximum 60 minutes. The whole of the horses make two journeys or one round trip, while a certain number do twice that amount of work. The working time is therefore 92 minutes for a single, and 184 minutes for a double round on the tramway, and 96 and 192 minutes for the same conditions in an omnibus. The work being 82 kilograms and 95 kilograms respectively, the duty realized is:—

In tramcars,	452,600 kilogs. per single, or	905,200 kilogs. per double trip.
„ omnibuses,	547,200 „ „ „	1,094,400 „ „ „

As the theoretical daily HP. equals 6,480,000 kilograms, it appears that the duty realized by a tramway horse does not attain to $\frac{1}{7}$, and may be less than $\frac{1}{14}$ of a steam HP. worked the 24 hours, or $\frac{1}{6}$ and $\frac{1}{12}$ by an omnibus horse.

The most favourable conditions realized are those on the long omnibus lines, 60-minute journeys, where two pairs of horses make two round trips daily respectively, 3,700 kilograms × 240, or 1,368,000, under which conditions the steam HP. is $4\frac{7}{10}$ times as much as that of the real horse. With a light carriage weighing 6 cwt., 62,000 metres were travelled in ten hours, giving a total work of 1,625,000 kilograms. This is the largest useful effect obtained.

The following figures give the tractive force required on different kinds of pavement:—

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	Kilograms. Per Ton.
Wood pavement, dry. Champs Elysées and Rue de Rivoli, trotting pace, average	15·196
Concorde, Rond Point, walk	16·620 19·570
Rond Point, Concorde, trot	17·270 17·560
Stone pavement, dry, exterior boulevards	14·360 17·200
Macadam " "	17·200 12·040
" watered, Quai de la Conference	16·770 18·990 17·910

H. B.

Traffic on the National Roads in France in 1882.

By E. Cheysson.

(Le Génie Civil, 1884, p. 215.)

The length of the national roads in France in 1814 was 33,162 kilometres; in 1882 it was 37,462. Since 1844 estimates have been made of the traffic at intervals of from five to seven years. Two measures have been adopted; the animals passing a given point in a day, and the tonnage of passengers and goods passing a point in a year. Tonnage is taken either as effective tonnage per kilometre, or as mean tonnage over a given distance. The choice of counting-stations requires care, as the vicinity of a town, a factory, a quarry, or the bifurcation of the road, will seriously affect the traffic. Four thousand three hundred and forty-four stations were fixed, giving a mean length for each section of 8,624 metres, the actual lengths varying from 3,500 metres in rich departments, to 17,000 metres in poorer and mountainous districts. The results will also be affected by the dates on which the counting is done, as bad weather, market-days, fêtes, pilgrimages, &c., cause irregularities. The counting was done on twenty-eight days in the year, at intervals of thirteen days.

The mean gross number of animals per kilometre per day, for the whole of France, was—

Loaded carts and wagons	102·7
Public conveyances (loaded and empty)	10·5
Empty carts and private carriages	106·6
	219·8

which is equivalent to 178·3 animals per kilometre, or 17·7 per hundred inhabitants, or 12·6 per square kilometre.

To convert animals into tonnage, the following have been found to be the mean weights—

	Kilograms.
Loaded carts and wagons	1,510
Public conveyances (loaded and empty)	950
Empty carts and private carriages	460

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These numbers are nearly in the ratio of 3 to 2 to 1. The mean weights of the horses drawing these vehicles are respectively 511, 453, and 430 kilograms. In the first case, therefore, a horse draws three times his own weight; in the second twice, and in the third a weight equal to his own. The mean gross weight drawn by a horse is 980 kilograms, or nearly 1 tonne, and the mean net weight 490 kilograms. The gross tonnage per kilometre is $219 \cdot 8 \times 980$ kilograms = 215 tonnes, and the net 108 tonnes. The net annual tonnage per kilometre is therefore $108 \times 365 = 39{,}400$ tonnes.

In Paris the traffic was divided into passenger and goods; the mean number of animals drawing the former being 2,665, and the latter 2,035 per kilometre. Taking 348 kilograms as the net weight per animal, the net tonnage per kilometre is 1,636 tonnes per day, or 597,000 tonnes per year. The mean annual tonnage on the French railways is 445,000 tonnes per kilometre per annum. Comparing the railways, navigable water-ways, and roads, the following figures are obtained:—

	Length in Kilometres.	Tonnage. Mean.	Tonnage. Kilometric.	Percentage of Kilometric Tonnage.
Railways . . .	24,383	445,394	10,801,259,457	75
Waterways . . .	11,968	182,000	2,174,531,000	15
National roads . .	37,462	39,400	1,480,148,000	10
Totals . . .	73,813	196,000	14,455,938,457	100

W. H. T.

Mekarski's Compressed-Air Engines on the Nantes Tramways.

By Edmond Boca.

(Le Génie Civil, No. 17, 1884.)

Mekarski's system of employing compressed air, heated by an admixture of steam, for the propulsion of tramcars has been in operation at Nantes for some years. The air-compressors and saturating heaters are of the kind usually employed by the patentees. A comparison of the compressed air supplied to the car engines with the capacity of the compressing cylinders shows the efficiency of the air-compressors to be 76 per cent. One kilogram (2·2048 lbs.) of air compressed to 30 kilograms (426 lbs. per square inch) supplies energy equivalent to 125,000 kilogrammetres, or 90,375 foot-pounds, and 100 kilograms are sufficient to propel a car of 8 tons weight for a distance of 12 to 14 kilometres (7·45 to 8·69 miles). The packing of the pistons of the second compressors proved troublesome, hard rubber rings and lignum vitæ did not stand, but satisfactory results have been obtained with manganese bronze. The tramcars at Nantes contain seats for 19 persons, a platform holding 15 or 16 at one end, and the heater

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and driver's cab at the other. The total length is 23 feet 3 inches, of which the heater and the driver's platform absorb one-seventh; the width is 7 feet 2¼ inches. The total weight is 6 tons empty, and 8 tons filled, while the weight utilized for adhesion is 4½ tons. The air is contained in ten cylindrical reservoirs placed underneath the platform, connected by pipes in two sets to form a working and a reserve battery. The contents of the former are 70 cubic feet, of the latter 28 cubic feet, together holding 220 lbs. of air at 426 lbs. pressure. The engines are attached to the outsides of the underframes, and enclosed in sheet-iron covers. Their diameter is 5¼ inches, and the stroke 10¼ inches, and the cut-off takes place at one-third of the stroke. The driving-wheels are 27⅝ inches in diameter. The cars are fitted with a Stilmant brake worked by compressed air. The heater is placed vertically on the platform, and has a capacity of 27·7 gallons, the water being heated to 150° Centigrade by means of an injection of steam previous to starting. By connecting the car reservoirs with the stationary accumulators a pressure of 20 to 25 kilograms is obtained in the former, which are then connected directly to the compressing pumps, and the pressure is brought to 30 kilograms, an automatic regulator turning the air again into the fixed accumulators when this limit has been reached. According to the state of the weather and the ability of the driver, the consumption of air varies, good drivers using at Nantes about 23 lbs. per mile, while inefficient men use up to 28·40 lbs. In 1883 the average consumption was 25·9 lbs., and during the first half of 1884, 24·6 lbs. The mean results obtained during the three years 1881 to 1883 are given in the Table below:—

——	1881.	1882.	1883.
Car journeys	5,582	5,338	5,515
Kilometres run	401,934	384,324	397,066
Cost per kilometre—	F. C.	F. C.	F. C.
Drivers' wages	0·060	0·062	0·061
Staff at stations	0·067	0·065	0·056
Fuel	0·117	0·117	0·101
Water	0·019	0·020	0·020
Lubrication of rolling plant	0·010	0·011	0·013
" of fixed plant	0·007	0·007	0·006
Maintenance of rolling plant	0·064	0·092	0·093
" of fixed plant	0·020	0·028	0·024
Sundries	0·008	0·006	0·004
Total	0·372	0·408	0·378

or 5·67, 6·25, and 5·76 pence per mile respectively.

During the first half year of 1884 the cost of fuel decreased to 7·9 cents, and the total cost to 34·3 cents, per kilometre, or to 5·22 pence per mile. The cost of horse-traction of the three omnibus companies at Paris during the same three years was

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0·612, 0·516, and 0·543 cents, per kilometre, or 9·39, 7·91, and 8·32 pence per tramcar-mile. This, however, includes a charge for renewal of horses, while it is not evident from the Table whether the maintenance of plant comprises a depreciation to provide for its eventual renewal, though the variations in the amount seem to indicate that depreciation or interest have not been taken into account in the calculation of the cost of traction.

C. B.

A Study of Street Communications in England, of the Modes of Paving and Cleansing them, and of London Tramways, &c.

By — BARABANT, Chief Engineer of Public Roads.[1]

(Paris, 1884.)

The Author visited London, Edinburgh, Glasgow, and Liverpool in March and April, 1883, accompanied by two other engineers, and his Report contains the results of their careful enquiry and observations on the traffic, lighting, cleansing, paving with stone, wood, and asphalt, together with some other general remarks on the appearance of the streets, as well as on the mode of construction of tramways. It chiefly refers to London.

Comparing London with Paris, he remarks upon the general absence of trees in even the widest streets, and although the large open spaces, the spacious parks and numerous squares, give a hygienic superiority to London, he expresses the opinion that the Bois de Boulogne, the Bois de Vincennes and the squares in Paris are more carefully tended, and have a more picturesque appearance. Stone-built Edinburgh is described as a very beautiful city; Liverpool and Glasgow as containing, in the principal streets, many buildings which are quite palatial, but, with the exception of Westminster Abbey and the Houses of Parliament, he saw little to admire in the monumental buildings of London as compared with those of Paris, and observed a remarkable paucity of handsome fountains or other ornaments to the streets, which have little besides the inelegant lamp-posts and refuges and the pillar-boxes to set them off. Beyond the boundaries of the city the houses are usually low and comparatively small, although healthy and comfortable, and whereas Paris, with its houses of six or seven stories, may be said to grow vertically, London grows horizontally, and every year extends further and further into the country; which extension he remarks is in a measure favoured by the non-existence of the troublesome *octroi*.

The underground railway he regards as of immense service to the population, and he was much struck with the lively appearance of the innumerable suburban railways. The management of the enormous street-traffic by a few policemen excited his admiration,

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and Tables are given showing the average daily traffic in the principal streets of London and Paris, the highest figures being respectively 26,793 in King William Street, City, and 6,005 in the Rue de Rivoli at the corner of the Rue du Louvre.

The arrangements for carrying off the sewage of London are inferior to those of Paris, the drains are small and generally inaccessible, whereas in Paris there are already 500, and will soon be 750 miles of large arched tunnels under the streets, which allow of water-pipes, electric and telephonic wires, pneumatic tubes, &c., being laid along them—this subterranean circulation being an enormous advantage. The innumerable overhead wires in some parts of the city of London seem to the Author to be dangerous.

The lighting of the streets by gas and by electricity; the numbering of the houses (sometimes so peculiar); the names of the streets (157 York Streets, 115 Church Streets, 119 John Streets, 109 George Streets, 99 Queen, and 95 King Streets); the 40 parish vestries; the attributes of the Metropolitan Board of Works, and the City privileges and those of the Lord Mayor, Aldermen, and Common Council, are successively described and submitted to friendly criticism. The watering and cleansing of the streets, which are fully reported on, he considers less perfect than in Paris, but whereas in the parish of Kensington the average cost is only 1 penny per square metre per annum, in Paris the average is 1¼ penny, the extent which is watered in the latter city being 8,300,000 square metres, with an expenditure of 1,494,000 francs.

The asphalt pavement is superior in London to that in Paris; the stone pavement, when laid as it now is with a substratum of concrete or cement, and composed of hard granite blocks, is also decidedly better than in Paris, but nearly twice as much money is spent yearly in England in keeping it in good repair; and, finally, the wood pavement in London has been of late years so greatly improved, and now offers so many advantages, that the Author advises its being largely adopted in Paris. The comparative duration and the cost of the three systems are examined in great detail.

The tramways of London and Liverpool are described, and the Author comments on the great variety of types of rail he met with, which seems to show that English Engineers are far from having as yet decided which is the best. Excluding those which have been already described in a work by Mr. Clark (of which a French translation was made by Mr. Dunod), diagrams and details are given regarding the rails and sleepers used by several tramway companies in the New Kent Road and Walworth Road, between Hammersmith and Richmond, and those of Liverpool, Manchester, and Edinburgh; the main conclusions which he draws from his careful examination being as follow:—

1. The rails should be of steel, very firmly fixed with bolts and screws rather than simple spikes. 2. The groove should not

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exceed 1 inch in width and depth, but wider on curves; on the outer side, against which the wheels press, the edge should be as straight as possible; 3. The rails should be laid on longitudinal rigid metal sleepers; 4. The line, as well as the adjoining pavement, should be laid upon a bed of Portland cement at least 6 inches deep, surmounted by a layer of sand $\frac{3}{4}$ to 1 inch thick, and the rail should be precisely at the same level as the surface of the pavement, which should be made of the hardest stone, and brought close up to the tram-rail; it should not be made either of asphalt or wood, which soon wear out; 5. All tramways should be solidly constructed, and the greatest care taken that they shall not require frequent renewal or repairs. Several types of French tramways are also described and compared with those in England, the solidity of which he strongly recommends for adoption in France.

O. C. D. R.

On Standard Patterns for Rolling-Stock on the Secondary Lines of the Prussian State Railways. By — Stambke.

(Verhandlungen des Vereines für Eisenbahnkunde in Berlin, 1884, p. 42.)

The importance of secondary lines having of late years greatly increased in Germany, 2,962·7 kilometres (1,840 miles) having been laid by the Government since 1879, the desirability of setting up standard patterns for rolling-stock became apparent.

Before deciding these, lists of questions relating to the construction and traffic of the then (1881) existing secondary lines—most of which were originally constructed as main lines—were sent to the different managers. The questions enumerated in these lists embraced the following points: length of line, maximum gradient, minimum radius of curves, load capable of being borne by rails, distance between watering-stations, number of trains per day, &c.; and whether it was deemed advisable to work the line in question with the ordinary main-line rolling-stock, or with other of special construction.

From the answers returned it was found that the maximum gradient was 1 in 35; the minimum radius in the case of only two curves was less than 180 metres (9 chains), but as a rule varied from 200 to 400 metres (10 to 20 chains). The maximum distributed load per wheel ranged from 5 to 7 tons.

Further reports made by the managers of the different lines decided that for lines with curves exceeding 12·5 chains radius, the wheel-base of the carriages is to be 5 metres (16·4 feet), that on lines where the curves are sharper the wheel-base should not be above 4 metres (13·1 feet), and that the maximum load borne by a single driving-wheel is not to exceed 5 tons, even in cases where from special causes a heavier permanent-way has been adopted. The only engines recommended are tank-engines with

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four- and six-coupled wheels. Special goods-wagons need not be provided, as those belonging to the main line travel over the secondary lines, and are built to suit them.

Standard patterns of the following classes of rolling-stock were agreed to at the conference held for that purpose.

1. Four-coupled tank-engines weighing 20 tons.
2. Six " " " 30 "
3. Four-wheeled coaches, 2nd and 3rd class, with 4- and 5-metre wheel-bases.
4. Four-wheeled coaches, 3rd class, with 4- and 5-metre wheel-bases.
5. Four-wheeled coaches, 4th class, with 4- and 5-metre wheel-bases.
6. Combined mail- and luggage-van, with 4- and 4·5-metre wheel-bases.

The dimensions of the four-wheeled tank-engines are:—

Diameter of cylinders	0·270 metre.	0·89 foot.
Length of stroke	0·550 "	1·8 "
Diameter of driving-wheels	1·080 "	3·5 feet.
Steam-pressure	12 atmospheres.	173 lbs.
Wheel-base	2·5 metres.	8·2 feet.
Total heating-surface	41·8 sq. metres.	450 sq. feet.
Grate	0·82 "	8·8 "
Capacity of tanks	2·5 cub. metres.	88·3 cubic feet.
" " bunkers	600 kilograms.	1,320 lbs.

The dimensions of the six-wheeled tank-engines are:—

Diameter of cylinders	0·350 metre.	1·1 foot.
Length of stroke	0·550 "	1·8 "
Diameter of driving-wheels	1·080 "	3·5 feet.
Steam-pressure	12 atmospheres.	173 lbs.
Wheel-base	3 metres.	9·8 feet.
Total heating-surface	60·389 metres.	650 sq. feet.
Grate	1·3 "	14 "
Capacity of tanks	4 cubic metres.	141·3 cub. feet.
" " bunkers	900 kilograms.	1,984 lbs.

It will thus be seen that it has been endeavoured to obtain in these engines the greatest possible heating-surface for the given maximum weight. The low rate of speed at which the trains of the secondary railways travel—15 to 30 kilometres (9·3 to 18·6 miles) per hour—enables a comparatively great tractive-force to be exerted. The six-coupled tank-engines are capable of developing from 240 to 260 HP., which at a speed of 15 to 30 kilometres (9·3 to 18·6 miles) per hour represents a tractive-force of 4,200 to 2,350 kilograms (9,260 to 5,180 lbs.).

An essential condition for this attainment was the adoption of small driving-wheels (3·5 feet diameter); with these there is no danger in maintaining a speed of 40 kilometres (25 miles) per hour, although 30 kilometres (18·6 miles) is the present limit allowed on secondary railways.

The cost of the four-coupled engines is £900, and that of the six-coupled engines £1,200. As regards the coaches they are all to be built on the American system. First-class compartments

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have up to the present not been provided, it being decided to wait until a demand for these springs up; on the other hand, although arrangements have been made for the construction of fourth-class coaches, it is not proposed to have them in all trains. The coaches are well ventilated and heated, and in all cases where practical lighted with gas.

All trains are fitted with continuous brakes (Heberlein's system), which are worked from the guard's-van.

J. R. B.

The Fractures of Bearing-Springs in Railway-Vehicles.

By H. Dunaj.

(Organ für die Fortschritte des Eisenbahnwesens, 1884, p. 128.)

It is generally supposed that the breakages of bearing-springs are due to inequalities in the road. The Author's experience, however, proved that they are rather due to defects in the springs themselves, as the fractures were seldom found to be fresh, but to have grown very gradually. In order to test the matter statistically, Table I. was constructed, showing all the fractures which occurred in four years on the Author's section of the Silesian railway, about 20 miles in length. They include vehicles from other railways passing over the line. In general one leaf only was broken, but occasionally two and rarely three or four. It was not always the uppermost leaf which broke, and the order of the broken leaves in the set was very variable.

From this Table the following conclusions are drawn:—

1. The largest number of fractures without exception take place in the cold season—a fact which also holds of tire-fractures; in the hottest season fractures are fewest.
2. In the spring of the last three years there have not been more fractures than in the months of August, September, and October of 1883.
3. Very few fractures, about one-sixth of the whole, were fresh, and most of them showed distinct flaws.
4. About one-third of the whole number took place during shunting.
5. In trains on the main-line, about one and a half time as many springs were broken as on branch-lines; but as the former is three times as long as the latter, and the traffic on it much greater, it follows that relatively there are far more fractures on branch-lines than on the main-line.

From No. 1 it may be deduced that cold is favourable to fractures, either indirectly through its action on the permanent way or from a direct injurious action on steel. Even the fresh fractures were most common in cold weather. Again, in Germany, the spring is always the worst season for permanent way, and hence it may be

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TABLE I.

Month.	1880.								1881.								1882.								1883.								Total in four years.
	Number of Fractures.																																
	Fresh Fracture.	Defect in Spring.	Old Crack.	On Main-Line.	On Branch-Lines.	In Shunting.	Unknown.	Monthly Total.	Fresh Fracture.	Defect in Spring.	Old Crack.	On Main-Line.	On Branch-Lines.	In Shunting.	Unknown.	Monthly Total.	Fresh Fracture.	Defect in Spring.	Old Crack.	On Main-Line.	On Branch-Lines.	In Shunting.	Unknown.	Monthly Total.	Fresh Fracture.	Defect in Spring.	Old Crack.	On Main-Line.	On Branch-Lines.	In Shunting.	Unknown.	Monthly Total.	
January .	..	4	6	2	1	6	1	10	3	15	3	10	6	4	1	21	3	3	3	3	3	2	1	9	2	5	2	2	2	4	1	9	49
February	3	7	3	7	3	2	1	13	1	3	4	2	1	2	3	8	2	3	5	3	..	3	4	10	3	4	5	3	5	4	..	12	43
March .	2	4	9	9	2	4	..	15	..	1	..	..	1	..	..	1	2	2	2	3	2	1	..	6	..	2	2	..	2	2	..	4	26
April .	..	2	8	1	3	1	5	10	1	1	..	2	..	..	..	2	2	1	2	..	1	3	1	5	1	3	1	2	1	2	..	5	22
May . .	..	..	..	..	..	..	..	..	..	2	1	1	1	1	..	3	1	..	3	3	1	..	..	4	..	2	2	1	3	..	..	4	11
June . .	4	1	..	3	..	1	1	5	..	1	..	1	..	..	..	1	..	3	..	..	2	1	..	3	..	..	..	..	..	..	..	..	9
July . .	..	2	..	..	..	1	1	2	..	1	..	..	..	1	..	1	1	..	1	..	..	1	1	2	..	1	2	..	1	2	..	3	8
August .	1	2	4	2	1	3	1	7	..	1	1	1	..	1	..	2	..	5	..	5	..	..	..	5	1	4	5	8	..	2	..	10	24
September	1	1	3	3	..	2	..	5	2	1	1	2	2	..	..	4	..	..	1	..	1	..	..	1	..	4	1	2	2	1	..	5	15
October .	..	3	1	3	1	..	..	4	1	1	1	1	1	..	1	3	1	1	3	3	1	1	..	5	2	1	1	1	2	1	..	4	16
November	1	1	3	..	2	2	1	5	3	5	4	7	2	3	..	12	3	11	..	3	8	3	..	14	..	8	2	3	2	3	2	10	41
December	..	2	1	1	2	..	..	3	1	1	2	1	1	1	1	4	..	3	2	1	1	3	..	5	2	3	1	2	..	3	1	6	18
Total	12	29	38	31	15	22	11	79	12	33	17	28	15	13	6	62	15	32	22	24	20	18	7	69	11	37	24	24	20	24	4	72	282
	Total for four years.																																
	50	131	101	107	70	77	28	282	Average 70·5 per year: 8·5 per year per mile of track.																								

TABLE II.

Month.	1880.					1881.					1882.					1883.					Total in four years.
	Number of Fractures.																				
	Fresh Fractures.	On Main-Line.	On Branches.	In Shunting.	Unknown.	Fresh Fractures.	On Main-Line.	On Branches.	In Shunting.	Unknown.	Fresh Fractures.	On Main-Line.	On Branches.	In Shunting.	Unknown.	Fresh Fractures.	On Main-Line.	On Branches.	In Shunting.	Unknown.	
January .	..	..	..	..	..	3	1	1	1	..	3	1	1	1	..	2	..	..	1	1	8
February	3	1	1	1	..	1	..	..	1	..	2	..	..	..	2	3	1	..	2	..	9
March .	2	1	..	1	..	..	..	..	..	..	2	..	1	1	..	..	..	..	.	..	4
April . .	..	..	..	..	..	1	1	..	..	..	2	..	1	1	..	1	..	..	..	1	4
May . .	..	..	..	..	..	..	..	..	..	..	1	1	..	..	..	..	..	..	..	..	1
June . .	4	3	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4
July . .	..	..	..	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	1
August .	1	..	..	1	..	.	..	..	..	..	..	..	..	..	..	1	1	..	..	..	2
September	1	..	..	1	..	2	2	..	..	..	..	..	..	..	..	..	..	..	..	..	3
October .	..	..	..	..	..	1	1	..	..	..	1	..	1	..	..	2	..	2	..	..	4
November	1	..	1	..	..	3	1	1	..	1	3	..	..	2	1	..	..	..	..	..	7
December	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	2	1	..	1	..	3
Total	12	5	2	5	..	12	6	2	3	1	15	2	4	6	3	11	3	2	4	2	50
	Total in four years.																				
	50	16	10	18	6																

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deduced from No. 2 that fractures are not mainly due to a bad state of the rails, &c. The same follows from No. 3, which also points to the true cause of fractures, viz., original defects; and as the speed in shunting is lower than in running, No. 4 also supports this conclusion, and points to a special cause of fracture. Lastly, although branch-lines are never so well maintained as main-lines, it appears that in four years only ten fractures occurred upon the branches, on which in this case the speed was also very low.

It is generally assumed that fresh fractures at any rate are always due to some sudden and violent strain thrown upon the springs. Table II., however, shows that in shunting the number of fresh fractures is larger than in running, although the speed is much less. The passage over the points and crossings is never so rough at this low speed as in itself to cause the fracture of sound springs. Some other cause must apparently be sought for. Again, the sixteen fresh fractures on the main-line, as shown in this Table, cannot altogether be attributed to the permanent way or the cold, from the well-known fact that all steel tends in time to become brittle under repeated vibrations and shocks.

A few special cases remain to be mentioned, (1) one of the fresh fractures included in the Table took place with a perfectly new spring, before the wagon had been moved. This must have been so brittle and hard that it could not support even the weight of the empty body. (2) On one occasion, in winter, two loaded wagons in a coal train upon the branch had each a spring broken; both fractures were fresh, no defect could be found in the permanent way, and no other fractures took place about the same period. The springs must have been too hard, or must have lost their toughness through age. (3) A wagon had been loaded with coal thrown in in lumps from a small height; it was then started by a horse, and one spring broke like glass. Only the main leaf remained whole, the others were broken in from two to six pieces each. Few of the fractures showed any old defects. The load in the wagon was about ½ ton more than its proper maximum of 10 tons. The wagon had been at work since 1876, and the spring had probably lost its elasticity.

Two defects in construction may be noticed in conclusion. The one is the hole pierced through the middle of each leaf for bolting them together, and the latter is the making of the second leaf pointed, and shorter than the main leaf. Both of these are apt to lead to fractures.

W. R. B.

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Point-Connection with Shearing-pin and Ratchet.

By A. Schön.

(Zeitschrift für Baukunde, vol. vii., No. 5.)

This is an arrangement by which, if the points are "run through," a minimum of damage is done to the connections, and by means of a detonator, attention is called to the fact. A joint is made in the connecting-rod near to the switch, as follows:—One of the ends to be joined is solid, the other tubular, the connection being made close to the extremity of the tubular end by means of a pin or cotter of strength enough to bear the ordinary working of the points, but not the strain put upon it when they are "run through." Beyond this cotter, and inside the tube, the solid rod has upon its top surface a row of ratchet teeth sloping opposite ways from a centre point, at which a spring-trigger pressed upon the hollow between the first teeth of the two ratchets, and, passing through the top of the tube, is held in position by a capsule, in which is a detonator, fixed to the outside of the tube. If the points are "run through," the cotter being the weakest connection is sheared, and the ratchet is forced along under the trigger, and by driving it up explodes the detonator, thus calling attention to the fact that the points have been forced. The pointsman working the points from a distance is also made aware of the accident, even if he does not hear the explosion, as the trigger holding in the ratchet and so shortening the connections prevents his getting the lever fully over when he tries to reverse the points. The arrangement is the invention of Chief-engineer H. Büssing, of the Railway-signal works of Max Jüdel & Co. of Brunswick.

W. B. W.

The New Town Waterworks in Stuttgart. By H. Zobel.

(Zeitschrift des Vereines deutscher Ingenieure, 1884, col. 557.)

Until the 1st of January, 1882, when the works described in this Paper were brought into use, the water-supply of Stuttgart was very bad. There was a State supply pumped from the River Neckar, and a Town supply from some reservoirs in the royal deer park, and from various wells and springs, the first two not being fit for drinking. After the consideration of many schemes, described at length by the Author, it was decided to obtain a new supply from the Neckar for all but potable purposes, and to construct the works in such a manner that an additional supply (fit for drinking) to be obtained from deep wells higher up the Neckar valley, could, in the future, be distributed with the former by a parallel system of pipes.

The water is conducted from the Neckar by a circular conduit,

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partly of concrete and partly of stonework, to the filter-beds, passing from which to a small clean-water reservoir, it is pumped to a high-service reservoir, from which it is distributed over the town. The filters consist of four basins of equal size (837 square yards), working independently of one another. The bottom is covered to a depth of 35½ inches at the centre, and 29½ inches at the sides, with gravel of different sorts, above which is a layer of 27½ inches of clean sand. The water stands about 4 feet 3 inches deep over the sand, through which and the gravel it percolates, and is collected by a system of trickling-drains, and conducted to a brick shaft outside the filter-basins. The total area of the filter-beds is 3,349 square yards. The highest daily yield per square yard of area, when three filters are in use, is 103 cubic feet; and when, as is usual, four filters are in use, 80 cubic feet per square yard.

There are two pumping-stations, one driven by water-power, and the other (as yet only occasionally used) by steam-power. These pump the filtered water through cast-iron pipes of 25½ inches in diameter, a distance of 2,231 yards, to the high-level service-reservoir. The water-power is made available by four undershot water-wheels of 16 feet 5 inches diameter and 13 feet 2 inches wide, each of which works two double-acting pumps by means of toothed wheels 13 feet 9 inches in diameter, one on each side of each water-wheel, and acting directly on the shaft, which is common to the two pumps. The normal number of revolutions of the water-wheels is 5·5 per minute, and of the pumps 22 per minute. The pump-cylinder is 7 inches in diameter, and the length of stroke 26 inches. The steam pumping-station, which is close to the filter-beds, is worked by two horizontal compound-engines of about 70 HP. These are as yet only used in flood-time or other emergencies. Ultimately, they will be used to pump the proposed additional supply, which is to be obtained from deep wells in the Neckar Valley into the service-reservoir.

The service-reservoir has a capacity of 342,570 cubic feet, with the water 11 feet 6 inches deep. It is made in two divisions, each 159 feet 9 inches × 101 feet 8 inches, covered in with parallel brick arches, of 11 feet 3 inches span, resting on brick piers, which again are pierced with arches of 8 feet 10 inches span, the intermediate piers being 4 feet 8 inches wide, and 1 foot 11½ inches thick, with buttresses on each side, 1 foot 11½ inches × 6 inches. These two divisions can be emptied separately. The walls are built of stone in hydraulic lime mortar, with a little Portland cement. The floor of the reservoir is formed of two courses of bricks in cement laid upon a bed of concrete. The inside, wherever the water has access, is coated with 0·4 inch of strong cement. The total cost of the service reservoir with buildings, drinking-water tank, valve-rooms, pipe-connections, tunnels for pipes, &c., was 8·8*d*. per cubic foot of available water-space.

The height of the service-reservoir is 279 feet above the level of the water in the wells, and 180·4 feet above the market-place

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of the town. This height commands the greater portion of the town, but there are still some parts which have to be supplied by the old waterworks.

The total cost of the works was:—

	£.
Construction	70,250
Land, buildings, and water-power	22,500
Management, furniture, &c.	3,950
Total	96,700

Something may be deducted from this sum as belonging properly to the drinking-water supply, which is not yet completed.

W. B. W.

Berlin Hygienic Exhibition. Report on Heating and Ventilation.
By C. HARTMANN.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, vol. xvi., 1884, p. 357.)

The various systems of ventilation were well illustrated, and there were numerous evidences of the increasing recognition of the fact that inclosed spaces in which men or animals congregate, or in which manufacturing operations are carried on, become more or less filled with vitiated and impure air. The extent to which air polluted with such foul gases and dust is injurious to the human organism, was clearly shown by the collection of diagrams and microscopic preparations exhibited by the Aachen Polytechnic School, and further the various lung-diseases caused by the inhalation of dust, as also samples of the different kinds of dust arising from manufacturing processes, were systematically displayed.

Numerous plans for exhausting the dust caused by grinding and pulverizing operations were exhibited, as also arrangements for conveying away the foul gases arising from match-making, the reduction of zinc ores, and other chemical processes. To this division would belong the appliances for removing sewer-gases injurious to health from the soil-pipes of closets, but the Author failed to find any examples of such apparatus in the Exhibition.

The altered sanitary conditions due to the use of electric light are noticed; and though the employment of electricity avoids the production of injurious gases, the facilities furnished for the removal of foul air, by the heat evolved in the combustion of gas, should not be lost sight of. Exactly opposed to the various processes for the abstraction of foul air from the points where it is produced, are those systems which aim at the constant introduction of pure atmospheric air from the outside. In connection with this subject, the choice of a source from which to derive the supply of air, and the careful purification of the air, when local circumstances render a pure supply impossible, are of the utmost im-

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portance. The Author discusses the different systems of collecting and purifying the air used for ventilating purposes.

The aerophore of Messrs. Treutler and Schwarz, of Berlin, furnished a means of disinfecting small volumes of air by passing it through a spray of disinfecting fluids. For the freeing of air from dust, long channels or large chambers were generally advocated, in some of which the air is made to take a zigzag course. In the air-chamber attached to the factory of L. Lammertz, of Aachen, are numerous shutters or partitions rising from the floor, which prevent the deposited dust from being blown up by the current of air passing through it. To increase the effectiveness of such dust-chambers, numerous filter-cloths were in some cases suspended. The wire gauze frequently used for this purpose can only retain the grosser particles, and better results are obtained by the employment of coarse canvas. A specially good air-filter was shown by Messrs. Möller, of Kupferhammer.

In the case of the filtering-apparatus for the air-supply of the Exhibition, carried out by Messrs. Rietschel and Henneberg, of Berlin, the filter-cloth, which was arranged in zigzag sheets, having a total area of 36 square metres, was composed of cotton-wool, sewn or quilted between two thicknesses of muslin. The thickness of this wadded sheet was 3 centimetres, and it proved capable not only of retaining all dust on the muslin surface, but also the greater part of the micro-organisms. The large superficial area compensated for the fineness of the filtering-material (cotton-wool). From experiments made by the Author, it was found that when 258 cubic metres of air were passed through each square metre in the hour, the resistance of the filter was equivalent to 2 kilograms per square metre (0·4 lb. per square foot), but when only 125 cubic metres passed through each square metre of filter-cloth in the hour, the resistance sank to 0·4 kilogram per square metre (0·08 lb. per square foot). Mention is also made of the wet system of air-filtration; excellent results follow the adoption of this plan, in that the dust particles, when moist, are more readily intercepted, because they then cake together freely. Various jet, or spray, ventilators were employed to effect this moistening of the air, and the apparatus for this purpose of different firms is described.

The same results are obtained by the more thorough washing or scrubbing of the air; and apparatus in which the atmospheric air is drawn or sucked through water was shown. Apparatus of this kind has the disadvantage of involving the use of air under pressure, and the different systems of washing do not thoroughly cleanse the air, as it always passes through the water in more or less minute bubbles, in the midst of which small particles of dust escape contact with the water. Various methods of moistening the air, by exposing it to large surfaces of water in shallow vessels arranged for rapid evaporation, were to be found at the Exhibition, and are described in detail. At the Dresden theatre the filter-cloths are kept wet with jets of water, to moisten the air; and in

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cases where very moist air is needed, as in certain spinning-mills, spray-producers have been adopted with success. Messrs. Körting Brothers, of Hanover, draw air by means of a steam-jet through a receiver filled with wet coke or pummice-stone. Steam alone is used by the Aachen Polytechnic School to impart moisture, and 50 per cent. of total saturation of the atmosphere is thus regularly obtained.

The various methods of changing the air in apartments, which depend on the difference in temperature in the internal and external atmosphere, are examined, as also those which are due to external air-currents, for which purpose cowls and hoods of all kinds are employed. Many contrivances of this character were shown in operation. The Author observes that their action in inducing currents was but slight; the chief value of the fixed and rotary cowls consists in their prevention of down-draughts.

The most satisfactory results are obtained when it becomes possible to employ mechanical power for ventilation. Apparatus may be driven by wind-power, water, steam, and electricity. Among the numerous plans for effecting artificial ventilation, that shown by F. Krupp, of Essen, is worthy of mention. He employs ordinary shafting-pulleys, to which fan-blades are attached. By causing these to run in cylinders or shafts communicating with the exterior of the building, the mere rotation of the shafting may be made the means of drawing in, or expelling, the air, according to the direction of the motion. Gas-motors are now much used for ventilation.

The position most advantageous for the air-inlets and for the escape of vitiated air, as well as the contrivances suggested for regulating and controlling the same, did not present any features of great novelty.

Many interesting inventions connected with atmospheric measurements, and with the detection of impurities in the air, are noticed. Among the former, mention is made of a very delicate manometer, for testing slight fluctuations in air-pressure by means of the action of the same on a surface of petroleum, exhibited by Professor Recknagel.

The section devoted to heating-apparatus was the most complete of all the departments of the Exhibition; it is here dealt with under, 1. Local, or simple heating apparatus; and, 2. Central, or combined heating arrangements. In the latter division are included all systems which aim at the warming of buildings or institutions from one central spot; and it is here that the greatest progress has been recently made. The Author deals with upwards of one hundred exhibits, which are classified in accordance with, whether they utilize heated air (calorifers), hot water, or steam. In many cases the system embraces a combined arrangement of heating and ventilation.

G. R. R.

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Mouras's Automatic Scavenger. By E. Thierry-Mieg.

(Annales Industrielles, August 24, 1884, p. 253.)

The Author has presented to the Industrial Society of Mulhausen a statement respecting the automatic scavenger, which has been in operation since the middle of the year 1883, at the works of Mr. Herzog at Logelbach, and which has fulfilled all the promises of the inventor. The cesspool with which the experiments were conducted was a cube constructed of brickwork in cement of 4 metres every way, and consequently of a capacity of 64 cubic metres (about 14,000 gallons). It was used for three water-closets, frequented by one hundred and fifty workpeople. When first employed it was three parts filled with water, and has since received a daily inflow of 10 litres of water per head, or a total volume of 1,500 litres of water (330 gallons) per diem, plus the dejections, liquid and solid, of the workpeople. The daily inflow was fairly constant in volume, and an exactly similar quantity of the contents was allowed to escape, maintaining the liquid in the cesspool at a uniform level.

The arrangement of the inlet- and outlet-pipes was in the form prescribed by the inventor.[1] The liquid issuing from the cesspool was received into a second tank, from which it was distributed over a large meadow and a vineyard. It was quite limpid, of a greenish colour, and emitted a faint odour of sulphuretted hydrogen, which, however, disappeared at a distance of from 80 to 100 metres; that is to say at the point where the liquid issued into the open air. At this point the sewage-water assumed a milky hue. The action of the scavenger has been so perfect that the Author is tempted to accept the theory advanced in *Cosmos*, that a complete putrefaction takes place, by which all fecal matters, solid and liquid, textile fabrics, paper, &c., are dissolved in the space of thirty days.

The chemical changes which go on in the cesspool may be summed up as follows:—Owing to the vessel being hermetically sealed, the phenomena of oxidation are practically prevented, the only available oxygen is that dissolved in the water added daily. The phenomena are simply due to hydration.

Sulphur derived from organic matters and biliary secretions, and nitrogen obtained from the urea and uric acid, give rise to the formation of hydro-sulphate of ammonia. The fatty matters are evidently converted by the free ammonia and the alkaline earths into ammoniacal and other soaps. The phosphates undergo no change whatever, and the manurial value is undiminished, because the nitrogen remains in compounds easy of assimilation by plants. The Author sums up the advantages of the system in the following terms:—The power of emptying into the cesspool domestic slops, greasy liquids, &c.; the suppression of all venti-

[1] Minutes of Proceedings Inst. C.E., vol. lxviii., p. 350; and vol. lxxii., p. 359.

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lators discharging mephitic gases into the atmosphere; permanent scavenging, without manipulation of any kind, and without soiling the premises and the courtyards; the recovery of a liquid product, of the density of pure water, having a smell greatly changed in character, and which liquid may be at once discharged into a watercourse or employed for irrigation.

G. R. R.

Report on the Progress of Hygiene in 1883.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, vol. xvi., supplement, p. 120.)

Disinfection.

Miquel has published the results of very accurate experiments on the protection of meat-infusion from putrefaction. He found that for this purpose it was necessary to add to 1,000 grams of the meat-infusion the following proportions:—

Of iodide of mercury	0·025	gram.
„ bichlorate of mercury	0·070	„
„ chlorine gas	0·250	„
„ sulphate of copper	0·900	„
„ salicylic acid	1·000	„
„ carbolic „	3·200	„
„ permanganate of potash	3·500	„
„ tannin	4·800	„
„ boracic acid	7·500	„
„ sulphate of iron	11·000	„
„ bisulphite of soda	275·000	„

For the disinfection of excreta it sufficed to employ 20 grams of sulphate of copper with 40 grams of sulphuric acid in 1 litre of water. For washing the sick, he advocates 1 gram of sublimate in 1,000 grams of water, and for the washing of clothing, 100 grams of sublimate in 1 cubic metre of water. He saw no utility in sulphurous acid.

According to the experiments of Perroncito, the spores of anthrax are killed by a solution—

Of 1 part of sublimate in	200 parts of water	in under 20	minutes.
„ 1 „ „ „	400 „ „	„ 35	„
„ 1 „ „ „	1,000 „ „	„ 120	„
„ 1 „ „ „	6,000 „ „	„ 87	days.
By a solution of 15 per cent. of sulphuric acid		in 8	„
„ dry heat of from 80° to 107°		in under 8	minutes.
„ „ „ 107° „ 115°		„ 6	„
In a hot fluid „ 80° „ 90°		„ 12	„
„ „ of 93°		„ 5	„

On the other hand, the spores retain their vitality—

In glycerine	for at least	281	days.
„ absolute alcohol	„	124	„
„ glacial acetic acid	„	87	„
„ 1 per cent. solution of carbolic acid	„	61	„
„ 5 „ „ „ „	„	26	„
„ 5 „ „ sulphuric acid	„	7 to 11	„

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Anthrax bacilli are less capable of endurance. They die—

In a 1 per cent. solution of sulphuric acid in from 5 to 15 minutes.
" common vinegar within 14 minutes.
" absolute alcohol at once.
" brandy in a few minutes.

Other experimenters found that the anthrax poison could resist for several days such an extreme degree of cold as prevailed during the severe winter of 1880–81; that exposed to a temperature of more than 65° and less than 100°, its activity diminished, and the more so the longer the heat was sustained, and that it was wholly deprived of vitality by a heat of 80° for two hours, or by a heat of 100° for twenty minutes in duration. In a dry condition, the virus needed exposure for six hours to a heat of 110° in order wholly to destroy its active properties.

Fresh and dry anthrax virus was rendered incapable of action—

By a	2 per cent.	solution of	carbolic acid	After a period not exceeding 48 hours.
"	1 " mille	"	salicylic "	
"	1 " "	"	nitrate of silver	
"	0·2 " "	"	sublimate	
"	fumes of bromine			

Fresh anthrax virus was deprived of its effect—

By a 5 per cent. solution of hypermanganate of potash.
" 3 " " chloral.
" 0·5 " " acetate of alumina.
" 2 " " benzoic acid.

It was not deprived of vitality.

By alcohol of 90 per cent. strength.
" saturated camphorated spirits of wine.
" tannin.
" borate of soda.
" sulphurous acid fumes.

The views of other authors are quoted with respect to the merits of sulphurous acid, sulphate of sesquioxide of iron, of naphthaline, and of bromine as disinfectants.

G. R. R.

Experiments on Substances used for Preventing Scale in Boilers.

By A. M. Friedrich.

(Organ für die Fortschritte des Eisenbahnwesens, 1884, p. 54.)

These experiments were made upon the following five substances:—

a. Crystallized Soda.
b. Alkalized Cellulose.
c. Belitz Powder.
d. Weber Powder.
e. Lapidolyd.

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TABLE A.

No.	Degrees of Hardness and peculiarities of water.	I.			II.						III.					
		Ordinary Unboiled Water from the Dresden Railway Station at Leipzig, taken at Dates as below :—			Same Water as in I., but boiled at 7 atmosphere-pressure in boiler of locomotive "Delphin." Taken at dates as under :—						Same water as I. and II., but after cooling down of the boiler mixed with substances as under :—					
											a. Crystallized Soda.	b. Alkalized Cellulose.	c. Belitz Pol e	d. Weber Powder.	e. Lapidolyd.	f. Nothing.
											Then raised again to 7 atmosphere-pressure. Taken at dates as under :—					
		Feb. 22, 1883.	Apr. 5, 1883.	Average.	Dec. 22, 1883.	Mar. 15, 1883.	Mar. 27, 1883.	Apr. 5, 1883.	Apr. 20, 1883.	Apr. 28, 1883.	Feb. 22, 1883.	Mar. 15, 1883.	Mar. 27, 1883.	Apr. 5, 1883.	Apr. 20, 1883.	Apr. 28, 1883.
1	Appearance of water.	clear	clear	clear	clear	clear	clear	clear	clear	clear	Powder Deposited at bottom of Flask.	clear	Coffee coloured; when Filtered, gold coloured, clayey deposit.	Somewhat Turbid.	Reddish Brown.	clear
2	Total degrees of hardness (including lime)	9·34	9·64	9·49	11·18	11·58	15·89	15·33	11·55	11·26	0·85	5·13	21·77	7·58	15·24	14·89
3	Permanent degree of hardness (incl. lime)	4·70	4·73	4·71	10·73	11·19	14·67	14·16	11·09	10·44	0·62	5·08	21·59	7·32	15·00	14·47
4	Common salt (degrees)	4·61	4·61	4·61	6·38	6·38	6·92	6·59	6·43	6·10	7·99	8·51	8·65	8·57	8·90	7·75
5	Figure of excellence.	28·05	28·44	28·25	49·75	51·51	66·82	64·40	51·34	48·68	10·70	29·08	95·19	38·11	67·20	66·05
6	Quality	excessively bad	do.	do.	bad	very bad	very bad	very bad	very bad	bad	good	excessively bad	very bad	bad	very bad	very bad
7	Special reactions . .	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
8	Total degrees of hardness (excl. lime) .	0·64	0·64	0·64	0·50	0·50	0·50	0·50	0·50	0·50	0·37	0·37	0·37	0·37	0·37	0·37
9	Permanent hardness (excluding lime) .	0·34	0·34	0·34	0·34	0·34	0·34	0·34	0·34	0·34	0·35	0·35	0·35	0·35	0·35	0·35

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TABLE B.—SYNOPSIS of FIGURES of EXCELLENCE.

No.	In 1 Cubic Metre of Water, one contained Salts as under:—	I.			II.						III.					
		Ordinary unboiled Water, from the Dresden Railway Station at Leipzig, taken at dates as below:—			Same Water as in I., but boiled at 7 atmosphere-pressure in boiler of locomotive "Delphin." Taken at dates as under:—						Same water as I. and II., but after cooling down of the boiler mixed with substances as under:—					
											a. Crystallized Soda.	b. Alkalized Cellulose.	c. Belitz Powder.	d. Weber Powder.	e. Lapidolyd.	f. Nothing.
											Then raised again to 7 atmosphere-pressure. Taken at dates as under:—					
		Feb. 22, 1883.	Apr. 5, 1883.	Average.	Feb. 22, 1883.	Mar. 15, 1883.	Mar. 27, 1883.	Apr. 5, 1883.	Apr. 20, 1883.	Apr. 28, 1883.	Feb. 22, 1883.	Mar. 15, 1883.	Mar. 27, 1883.	Apr. 5, 1883.	Apr. 20, 1883.	Apr. 28, 1883.
1	Free carbonic acid	Grams. 2·36 1·18 L	Grams. 2·36 1·18 L	Grams. 2·36 1·18 L	Grams. 1·26 0·63 L	Grams. 1·26 0·63 L	Grams. 1·26 0·63 L	Grams. 1·26 0·63 L	Grams. 1·26 0·63 L	Grams. 1·26 0·63 L	Grams. 0·16 0·08 L	Grams. 0·16 0·08 L	Grams. 0·16 0·08 L	Grams. 0·16 0·08 L	Grams. 0·16 0·08 L	Grams. 0·16 0·08 L
2	Sulphate of magnesia	7·29	7·29	7·29	7·29	7·29	7·29	7·29	7·29	7·29	7·50	7·50	7·50	7·50	7·50	7·50
3	Carbonate of lime	154·83	161·78	158·31	50·67	48·61	70·47	69·19	50·93	60·18	12·35	43·98	47·33	49·38	48·87	53·50
4	Sulphate of lime (gypsum)	65·10	65·83	65·46	211·57	222·74	307·27	294·88	220·31	204·52	..	74·09	474·11	128·49	315·04	302·17
5	Chlorine compounds	96·26	96·26	96·26	133·21	133·21	144·49	137·60	134·26	127·37	166·83	177·69	180·61	178·94	185·83	161·82
	Total items, 2 to 5	323·48	331·16	327·82	402·74	411·85	529·52	508·96	412·79	399·36	186·68	303·26	709·55	364·31	557·24	524·99

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The method was as follows:—A measured quantity of water was placed in the boiler of an experimental locomotive, and steam was then got up to an effective pressure of 7 atmospheres. A sample of water was then taken out and tested. The pressure was then let down to nothing, and the substance to be tested sprinkled in the boiler. The pressure was again brought up to 7 atmospheres, and a second sample taken and tested. By subtracting the amount of gypsum found in No. 2 sample from that of No. 3 sample, the effect of the substance can be calculated.

It will be seen in Table A, No. I., that the water as supplied had altered very little in the six weeks that elapsed between the beginning and end of the experiments. The figures in No. II. are higher than in No. I., showing that the water had dissolved a certain quantity of old scale. From the figures thus obtained, and after the subtraction mentioned above, the quantity of each substance in grams per cubic metre of water can be calculated. The figures thus obtained are given in Table B. From this Table it may be proved that neither Belitz powder nor Lapidolyd diminish in the least the amount of gypsum in the water, while Weber powder and cellulose do so in part, and soda removes it altogether. Similar deductions may be made with regard to other impurities.

In order to settle the question of cost, it must be found what quantity of the different substances must be introduced, in order to diminish the gypsum by the same amount. It is easily proved that this depends solely on the quantity of soda they contain, this being the one efficacious element. The reaction, in the case of soda, is as follows:—

Gypsum = CaO, SO_3. Soda = NaO, CO_2.

These by reaction become:—

NaO, SO_3 = Glauber salt. CaO, CO_2 = carbonate of lime.

Working out the results in the case of the five substances considered, the proportionate cost, taking soda as unity, is as follows:—Cellulose, 4·74; Belitz powder, infinity (no effect); Weber powder, 7·39; Lapidclyd, 27·39. These results, which have been confirmed by others' experience, are very remarkable, as showing the superiority of common soda to more complicated and more vaunted materials.

W. R. B.

Portable-Engine Tests. By F. Schotte.

(Der Civilingenieur, 1884, p. 237.)

This Paper contains the results of some very exhaustive tests of portable engines, made by the Agricultural Society for the Mark

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Brandenburg and the Niederlausitz. Six engines were tested, viz.:—I., an 8-HP. portable, by R. Dolberg of Rostock; II., a 10-HP. portable by R. Wolf of Buckau; III., an 8-HP. portable, by Oluf Onsum of Christiania; IV., a 10-HP. portable, by Feodor Siegel of Schoenbeck; V., a 12-HP. compound-portable, by Ruston Proctor and Company of Lincoln; VI., a 40-HP. (effective) semi-portable compound condensing-engine, by R. Wolf of Buckau.

All the engines had single cylinders, except the two compounds. The principal dimensions were as follows:—

——		I.	II.	III.	IV.	V.	VI.
Diameter of cylinder	inches	$9\frac{11}{16}$	$8\frac{1}{8}$	$9\frac{1}{4}$	$7\frac{1}{16}$	7 11	11 $18\frac{1}{2}$
Stroke	„	$13\frac{15}{16}$	$11\frac{13}{16}$	$14\frac{7}{16}$	$14\frac{15}{16}$	14	$15\frac{3}{4}$
Revolutions per minute		114	130	106	138	128	88
Boiler-pressure	lbs.	59	102	69	96	118	83
Grate-surface	sq. ft.	5·7	2·8	5·3	3·4	6·2	6·6
Heating-surface	„	151	150	176	150	213	452
Number of tubes		27	43	31	37	50	92
Diameter of tubes	inches	$2\frac{1}{2}$	2	$2\frac{13}{16}$	$2\frac{1}{8}$	$2\frac{1}{8}$	$2\frac{1}{4}$
Water in boiler	lbs.	1,612	1,764	1,544	2,205	1,996	8,820

All the engines had steam-jacketed cylinders, and were provided with feed-water heaters. Wolf's engine (No. II.) had an Allen-Trick slide-valve, and his compound-engine (No. VI.) had a separate expansion slide on the high-pressure cylinder under control by the governor on the Rider (Bodmer) system; Ruston Proctor and Company's engine (No. V.) had also an expansion slide on the high-pressure cylinder, controlled by the governor through a link. The remaining three engines had ordinary single slide-valves.

The Dolberg engine was intended for burning turf, and a special test (No. VII.) was therefore made with this engine with turf as fuel.

The coal used was Upper Silesian coal, which had by analysis a heating power of 13,185 British units of heat per lb. of coal: The heating power of the turf used in the last test was 5,969 units of heat per lb. of turf. In order to test the efficiency of the combustion, periodical analyses were made of the furnace-gases in the smoke-boxes; these analyses showed the excess of air to be as follows, the theoretical air quantity being 1:—

	I.	II.	III.	IV.	V.	VI.	VII.
	Dolberg.	Wolf.	Onsum.	Siegel.	Ruston.	Wolf.	Dolberg.
Excess of air	0·8	0·7	0·4	0·6	0·5	1·2	0·8

The heat of the coal was utilized in the following proportions, which were calculated from the experimental data; the figures give percentages of the heating power of the fuel.

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——	I.	II.	III.	IV.	V.	VI.	VII.
Utilized in steam . . .	52·2	57·0	60·3	57·1	58·8	55·9	63·2
Lost by furnace-gases, soot, and ashes	37·2	24·9	24·7	28·2	27·9	24·9	24·9
Accounted for by conduction	6·1	6·7	5·6	4·6	6·0	7·1	8·1
Unaccounted for	4·5	11·4	9·4	10·1	7·3	12·1	3·8
	100·0	100·0	100·0	100·0	100·0	100·0	100·0

In order to make the heat-calculations and evaporative tests reliable, the boilers were very carefully and continuously tested for priming by Brauer's process, which consists in mixing a very slight percentage of salt with the water when the boiler is first filled up, and analysing the water in the boiler from time to time, and examining also, as a check, the condensed water from the cylinder cocks. This very delicate process proved that Siegel's boiler (No. IV.) was the only one which showed any signs of priming, the amount of water mechanically carried by the steam was, in this case, 1·7 per cent. as a mean. The steam was therefore delivered practically dry from nearly all the boilers.

The engines were all fired by the same stoker, and were tested on successive days by a ten-hours' continuous run at the friction-brake, the brake being loaded in each case to give the horse-power the maker elected to run against. Indicator diagrams were taken from both ends of the cylinders at short intervals.

The following Table gives the principal results obtained:—

——	I.	II.	III.	IV.	V.	VI.
Boiler pressure . lbs. per sq. in.	59	102	69	96	118	83
Temperature of feed . . . ° F.	137	160	131	113	136	92
Water evaporated per lb. of coal lbs.	6·4	7·1	7·4	6·8	7·1	6·6
Mean HP. on brake	8·2	14·8	19·9	14·5	29·1	48·2
Mean indicated HP.	11·0	17·8	22·5	19·8	34·8	55·5
Mechanical efficiency of engine .	0·74	0·83	0·89	0·73	0·83	0·87
Steam per HP. (brake) per hour lbs.	62·7	30·6	44·3	45·3	27·1	19·5
Coal per HP. (brake) per hour „	9·8	4·3	6·0	6·6	3·8	3·0

The Paper contains drawings of the engines, and full particulars of their general construction. Examples of the indicator diagrams are given, and details of the brake used, and exhaustive details of the methods of testing, and complete tables of results.

W. P.

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On the Superheating of Water in Steam-Boilers.

By — HIRSCH, Ingenieur en Chef des Ponts et Chaussées.

(Annales des Mines, vol. v., 1884, p. 171.)

The theory advanced by Mr. Trève, that the greater number of boiler-explosions is due to superheating of the water and subsequent sudden conversion of the same into steam on experiencing a disturbance, is examined in this Report.

The Report embraces an inquiry into causes of boiler-explosion, extending over five years, 1878–82, together with experiments on the nature, causes, and conditions of superheating, and more particularly experiments carried out in a boiler devoted to the purpose, in which means were provided for indicating thermo-electrically and registering any important differences of temperature that might be set up between the water and steam in the boiler. These enquiries and experiments, coupled with the results of much private investigation and scientific opinion, induce Mr. Hirsch to report that—

It is in no case demonstrated that the cause of any boiler-explosion has been superheating.

If such has, indeed, ever been the case it must have been through a rare concourse of exceptional circumstances.

There is not sufficient evidence to render necessary an examination of the various remedies proposed to deal with superheating.

The use of an instrument indicating exactly the temperature of the water, and the pressure of saturation corresponding, might afford indications promoting a knowledge of the subject, provided such instrument was used with proper care and precautions.

J. J.

Hydraulic Forging.

(Karmarsch und Heeren, Technisches Wörterbuch, vol. vii., pp. 754–765.)

John Haswell was the first to apply hydraulic pressure for the purpose of forging in 1861, when he constructed an 800-ton press for forging parts of locomotives. The advantages of this method are, that the cast-iron dies into which the metal is forced are not so easily damaged as when they are subjected to the blows of a hammer; the forgings may also be of somewhat complex shape and a very homogeneous forging is produced, as the pressure must distribute itself through the entire mass of metal before it can assume the desired shape. Since the original outlay on the dies is considerable, the process will not prove economical unless at least about ten forgings after the same pattern are produced, while for much greater quantities it is exceedingly remunerative.

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A 2,000-ton press is fully described and illustrated. There are two plungers of different diameters which are externally rigidly connected by means of cross-heads and links. The water under pressure enters above the larger or working piston, which is made to move in a vertical cylinder connected by four pillars with the base. The upper die is attached to the lower end of the plunger, while the lower die is fixed in the base. The small plunger moves above the other for the purpose of raising it after a forging has been completed. This plunger is continually under hydraulic pressure applied below, and when it is desired to raise the large plunger, it is only necessary to release the pressure on it. This is effected by means of valves which are worked by steam-pressure. The weight of the plunger causes it to descend until it comes in contact with the forging, when the pumping engines are brought into operation.

Details of the process of manufacture in the cases of a crosshead, a wheel in four parts, and a disk-crank are given as examples. To make the manufacture continuous for each press a steam-hammer and two heating-furnaces are needed. In one day of ten hours twenty-five to thirty cross-heads for locomotive engines are manufactured. Figures are given showing a reduction of 65 to 70 per cent. on the cost of making forgings in the ordinary manner with the aid of a steam-hammer.

C. F. B.

The Effect of the Chemical and Physical influences occurring in Practice on Basic Fire-proof Materials.

By A. WASUM, Bochum.

(Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1884, p. 104.)

Since the introduction of the Thomas-Gilchrist process, the bases calcium and magnesium, and the mixture of both, known as dolomite, occupy a very important place among fireproof substances.

Used alone their capacity to resist the action of heat is as great as that of the best other refractory materials, but when in addition to heat they are simultaneously subjected to chemical action the case is different. For the purpose of investigating their behaviour under the latter conditions the Author undertook a series of experiments, in carrying out which he was guided by the following considerations.

The basic firebricks employed in the production of steel consist of lime, magnesia or dolomite, with or without some binding material; as a rule the latter is not used, but when it is, consists in practice exclusively of clay; on this account only that material was used for the experiments.

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In all the processes in which basic bricks are employed they are exposed to the chemical action of the acids and metallic oxides formed, as well as to the high temperature, and therefore the combined effect of these acids and oxides and great heat was investigated. As in the processes referred to, it often happens that the furnaces and smelting-apparatus have to be suddenly cooled with water, in order to enable repairs to be undertaken, the result of cooling heated basic bricks with water also formed the subject of experiment. All the experiments were carried out with minerals occurring in nature, *i.e.*, dolomite, carbonate of lime, magnesia, and magnesite.

The bricks were made in the same way as in actual practice; some of the above materials only, others with the addition of one of the substances, the effect of which was to be investigated; these substances were alumina, silica, phosphoric acid in the form of phosphate of lime, and phosphate of magnesia, basic converter-slag, iron monoxide, iron sesquioxide, and magnetic oxide of iron. All the bricks were subjected to a temperature sufficiently high to melt steel; on cooling they were measured to determine the contraction which had taken place, then one portion was kept in dry air to test their durability under these conditions; a second portion was made red hot again and cooled with water; a third was treated in the same way, but then made red hot a third time, and kept in dry air until the bricks fell to pieces.

The Author gives the results of the experiments in a tabular form, showing the amount and nature of the foreign material mixed with the basic brick, the contraction after heating and cooling for each dimension, the time after which the brick fell to pieces under the various conditions already specified, with notes as to its appearance, &c., in each case. Dolomite and limestone required no binding material in order to form good bricks, but this was not the case with magnesite; in all cases, however, the bricks were much improved by the addition of clay, and when this was used first-rate bricks could be made of magnesite. If the materials were not very impure, as much as 5 per cent. of clay might be added without materially affecting the capacity of the bricks to resist heat.

The experiments showed that for all the purposes required magnesite and magnesia were the best materials, as they had a much greater durability than the other substances tried, many of the bricks formed of them lasting over three months after being subjected to the treatment mentioned, while the best of those made of carbonate of lime or dolomite fell to pieces after periods varying from a day to a month, according to the treatment and the admixture of foreign substances.

The worst effects were produced on basic bricks by the various oxides of iron; silica, phosphoric acid, and the oxides of manganese are not so deleterious.

As regards contraction, bricks of magnesite and magnesia are much superior to those of lime and dolomite.

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The following analyses show the composition of the magnesite. dolomite, and limestone used:—

	Per cent.	
Magnesia	44·98	Magnesite.
Lime	1·69	
Silica	0·13	
Alumina	0·84	
Iron monoxide	1·63	
Manganese monoxide	0·29	
Carbonic oxide	50·57	
Lime	31·62	Dolomite.
Magnesia	20·19	
Silica	1·70	
Alumina	0·09	
Iron monoxide	1·22	
Manganese monoxide	trace	
Carbonic acid	45·35	
Carbonate of lime	98·80	Limestone.
Insoluble residue	1·07	

G. R. B.

Arrangements at the Lead Smelting-Works near Ems for extracting, condensing, and collecting Lead Fumes.

(Die auf der Bleihütte bei Ems zur Gewinnung des Flugstaubs getroffenen Einrichtungen, von M. Freudenberg. 8vo. Ems, 1883.[1])

Elaborate experiments have been made at these works with the object of minimising the loss of lead in the flues connected with the smelting-furnaces.

The methods tried may be divided into two classes.

1. Those in which water is used.
2. Those in which it is not.

The former of these proved unsuccessful, and, after a brief trial, was abandoned, and has not since been resumed.

The dry method may itself be divided into three processes.

1. The collection of particles mechanically carried off from the furnaces.
2. The condensation of particles carried off in a gaseous state.
3. The collection of those condensed particles.

Since the enlargement of the works in 1874 spacious chambers and narrow flues have been tried alternately, with a view of ascertaining which system afforded the best results. The system of flues extends from the smelting works to the top of a hill 1,700 metres distant from, and 178 metres above, the floor-level of the furnaces. The flues in the blast furnace are made of sheet iron 1·5 millimetre thick, and are suspended 30 centimetres over the mouth of the furnace. The floors of these flues, which lead into the main flue, are so constructed as to form a series of inverted hutches, pyramidal in transverse section, in which the

[1] The original is in the Library of the Inst. C.E.

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fume collects, and from which it is removed through a door opening downwards in each division. A section through one of these dentals forms a triangle, with a base 2 metres long and 1 metre deep. The fume is removed from them by means of a pipe and funnel placed beneath. The flues outside the furnace buildings are constructed of brick, and vary in size according to the amount of smoke passing through them. A cheap method of building consists in roofing the flues with jack arches springing from old rails. A flue with a roof of this description, rectangular in section, 3 metres broad and 1·50 metre high, has been found to give the best and cheapest results. The height of the main chimney is 42 metres, its diameter at the bottom 2·47 metres, and at the top 1·80 metre. As it was deemed likely that the chimney would create a greater draught than was necessary to work the furnaces, a circular iron plate, acting as a damper, was fitted into it and connected with an external lever by which it could be set at any desired angle. When the works are in full operation the plate is inclined 45°. Before the last system of chambers was built the angle of inclination was 27°.

Observations on the temperature of the gases were made at various points, from which it appears that they cooled from 136° Centigrade (277° Fahrenheit) at a point relatively near the furnaces to 64° Centigrade (147° Fahrenheit) at the exit from the last series of chambers. The temperature on the floor of the flues is invariably a few degrees lower than under the arches. Where the average temperature was 136° Centigrade, the difference was 8° Centigrade (14°·4 Fahrenheit); at the foot of the chimney it was only 2° Centigrade (3°·6 Fahrenheit).

There are five Piltz blast furnaces at work, around each of which is fixed a sheet-iron cylinder, 2 millimetres thick, and placed at a distance of 1 metre from the outer circumference of the furnace and 1·5 metre from the floor. This cylinder or jacket is open at the bottom; at the top it communicates with a pipe 50 centimetres in diameter, leading to a chimney 18 metres high and 43·5 metres above the level of the furnace. By this arrangement results are produced similar to those obtained at other works through the agency of exhausters.

A Table exhibits the results of the various observations made from December 1875 up to August 1881. It shows the internal superficial area and cubical capacity of the flues at work during the respective periods enumerated, as well as the results per 100 superficial metres of rubbing surface, and per 100 cubic metres of capacity. The cubical contents are only important where the proportion of the superficial area to the cubical contents has been altered. This was the case in the first four periods.

The flues first built were too narrow; wider ones were therefore substituted, and the whole system was enlarged to meet the increased requirements of the works. The mean sectional areas of the flue gradually grew until they reached the standards it is now intended to adopt, *i.e.*,

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	Square Metres.
In the first period	1·79
„ second period	2·16
„ third „	3·21
„ fourth to sixth period . . .	4·08

It is argued that the conclusion to be formed, from the fact that the quantity of lead decreased on widening the flues, is, that the particles in the smoke are deposited in proportion to the superficial area of rubbing surface, and are in no way dependent on the sectional area.

Better results were obtained in the last two periods owing to the draught being better regulated, the damper being always kept as far closed as the working of all the furnaces permitted.

From October 1st, 1880, to August 11th, 1881, 14,605,261 kilograms of lead ore were smelted, which gave 6,247,605 kilograms of lead; of this latter amount the proportion of lead obtained from the fumes was equal to about 8 per cent. on the quantity of ore treated.

A Table shows how the quantities of deposit were distributed over the whole system.

A remarkable feature in this Table is the great quantity of lead deposited per square metre in the divisions I. and V.

In division I. this is partly accounted for by the particles mechanically carried off having a greater tendency to settle in the lower part of the system; but the Author is of opinion that it is more due to the fact that divisions I. and V. are above ground, and consequently the temperature of their walls would be less than in divisions II., III., and IV., which are built below the ground, and therefore absorb and retain the temperature of the gases which pass through them. The condensation of the particles, therefore, also depends on the temperature of the walls.

The Author proceeds to show that the amount of fume deposited in the upper divisions of the flues greatly exceeds that in the lower, and accounts for it on the presumption that the gases are better able to cool in the former, the only difference between the two divisions being that the lower is enclosed by thick walls, whereas the upper is covered by a comparatively slight roof; he concludes that the increase in the deposits was also due to the great difference in the temperature of the gases, which in division X. was 89° Centigrade (192° Fahrenheit), falling to 64° Centigrade (147° Fahrenheit) in division XV. The amount of lead per 100 superficial metres, returned from division XVII., is inaccurate, as the lead from the chimney was also included in this. It is shown that, besides lead, consideration must be taken of the silver contained in the lead; this amounted to 51·86 grams per 1,000 kilograms, or a total quantity of 48 kilograms of silver. The greatest quantity of silver was found in the flues nearest to the blast-furnaces, whilst at the end of the system the deposited particles only contained 30 grams per 1,000 kilograms. The contents of zinc fluctuated between 3 and 5 per

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cent., slightly more being found generally in the lower flues; this was also the case as regards antimony, which varied between 0·27 and 0·40 per cent. The deposit on the floor of the flue generally contained 10 per cent. more lead than that on the arches. The Author sums up by pointing out that the previous part of the Paper had clearly demonstrated two important facts:

(1.) That the condensation and collection of gaseous particles is of more importance than the collection of particles mechanically carried off in the furnace-smoke; and (2) that this purpose is effected, first by providing ample rubbing-surface in the flue-walls, and secondly, by the cooling of the gases. On these hypotheses it was then sought to improve the system so as to increase considerably the amount of fume recovered from the furnace-smoke; and as at Ems it was found impracticable to make any decrease in the temperature of the gases, such improvements were necessarily restricted to an increased superficial area of wall or rubbing surface, which was most economically effected by the introduction of plates into the flues made as thin as possible, so as not to impede the draught. These plates were either fixed upright on the floor or hung from the roof, as the section best permitted, and were placed edgeways or parallel to the walls of the flue. They were made of different materials according to the temperature of the place in which they were fixed, old sheet iron, worn-out jigger sieves, and cardboard being used at Ems for this purpose; but the Author suggests that further experiments might advantageously be made in this direction.

In order to prevent the draught from the chimney carrying off particles in suspension, small walls are built across the flues at distances 5 or 6 metres apart at right angles to the direction of the draught, their height being regulated by the strength of the draught. By the introduction of these plates and walls it is asserted that, with an increase of only one-tenth the cost, twice the amount of lead has been recovered: and, consequent upon its successful application at Ems, the Author has been induced to take out a patent for the system in the name of the Ems Lead and Silverworks Company.

These arrangements are equally well suited to the recovery of metal from gases escaping from chemical works.

The great saving of flues supplied with iron sheets over brick flues is demonstrated by the following figures: the sheet cost £905, and it is estimated that the same surface-area in brick flues would have cost £14,328, almost sixteen times as much, a saving of £13,423 thus being effected by the former. The actual cost of the whole condenser was £13,663.

G. S.

NOTE.—In reference to the present abstract it may be mentioned that a patent for the recovery of fumes was taken out in 1880 by Messrs. E. A. Cowper and Thomas Sopwith, MM. Inst. C.E. In this case, however, the diaphragms were laid horizontally in the flues instead of being hung vertically as in Mr. Freudenberg's plan.—G. S.

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Electric Transmission of Power in Mines.

By Prof. W. S. Schulz.

(Zeitschrift des Vereines deutscher Ingenieure, 1884, p. 149.)

The Author deduces, from the executed electrical transmissions of power tabulated below, that the maximum electrical efficiency of the receiving-dynamo practically attainable is 50 per cent. of the transmitting motor:—

Name of Pit.	Power of Motor.	Machine Driven.	Length of Lead.	Efficiency.		
				Electrical.	Mechanical.	Total.
	HP.		Metres.	Per cent.	Per cent.	Per cent.
La Peronnière, near Rive-de-Gier	37·1	Hauling-Machine	1,500	50·0	37·0	30
Thibaut, near St. Étienne	5·0	"	250	45·0	38·0	25
Blanzy	17·0	"	634	..	51·0 ?	30
Zaukeroda	14·7	Locomotive	893	46·6 ?	37·8 ?	30
"	5·0	Fan	780	50·0	26·0 ?	..
St. Claude, near Blanzy	8–10	"	900	..	..	..

On this basis he compares the cost of electrical transmission of power with the actual cost of transmission by compressed air and water applied to rock-drills and coal-getting machines, locomotives, cable and rope hauling-machines, and ventilators. He finds the former more costly than other methods, except where air is compressed by steam power without being cooled, and in the case of locomotives for haulage on levels. The comparative cost of such haulage in actual operation is given in the Table:—

Underground Haulage by Locomotives.

—	Steam.		Compressed Air.		Electricity.
	Dornan Pit.	Cesson Pit.	Pétan's System.	Mékarski's System.	Zaukeroda Pit.
	Marks.	Marks.	Marks.	Marks.	Marks.
Cost of plant	32,000	32,000	13,000	20,000	16,000
	d.	d.	d.	d.	d.
Interest, &c., per ton-kilometre	0·264	0·091	0·490	0·502	0·276
Cost of haulage " "	0·372	0·316	0·736	0·841	0·680
Total cost " "	0·636	0·407	1·226	1·343	0·956
	Ton-kms.	Ton-kms.	Ton-kms.	Ton-kms.	Ton-kms.
Daily work	488	1,421	106	159	235
	Metres.	Metres.	Metres.	Metres.	Metres.
Length of line	2,320	4,627	620	620	620
Speed "	2·3	3·3	1·5	1·5	2·6
	Kilograms.	Kilograms.	Kilograms.	Kilograms.	Kilograms.
Weight of engine	4,400	8,000	2,700	2,300	1,600
	Metres.	Metres.	Metres.	Metres.	Metres.
Height " "	1·92	2·1	..	1·55	1·5
Width " "	1·30	1·6	..	1·10	0·8

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For the separate ventilation of a lateral drift of the Zaukeroda mine[1] a 40-inch Schiele's fan is used, driven by a Siemens dynamo actuated by a Dolgorouki steam-engine; the cost per 1,000 cubic metres is 0·27*d*., which is cheaper than transmission by compressed air only where a special compressing plant for the small fan has to be put down. The Author concludes that there is no field for electrical transmission in mining, special cases excepted, except for hauling on levels by locomotives, which could advantageously replace rope- or cable-haulage.

C. B.

Electricity as a Motive-Power on Railways.

By Baron Gostkowski.

(Wochenschrift des österreichischen Ingenieur- und Architekten-Vereins, 1884, vol. ix., p. 29.)

The Author first inquires into the use of primary batteries (instancing Page's locomotive, 1850), and then into the employment of accumulators, showing that they can not at present be adopted for ordinary railways on inclines on account of their weight. He then passes to the cases in which the current goes direct to the electromotor on the locomotive, first introduced by Siemens (Berlin, 1879). In this instance the current passes from the two rails through the wheels. In the case of the electric locomotive at the Paris Exhibition (1881), and the recently opened line between Mödling and Brühl, the current passes to the electromotor through a copper tube the whole length of the line, in which slides a piston which the car draws along with it. On the Portrush Railway there is a third rail on which runs a contact wheel forming the positive lead, the two running rails forming the negative. Which of these three systems is best yet remains to be seen. The following applies to all: the mechanical work necessary to supply a current of i amperes and E volts is

$$\frac{i \,.\, \mathrm{E}}{g} \text{ kilogrammetres,}$$

Where g is the acceleration $= 9 \cdot 81$ metres. The available work of the motor will be

$$\frac{i \,.\, e}{g} \text{ kilogrammetres,}$$

where e is the electromotive force at the motor. The loss of work is $\frac{i}{g}$ $(\mathrm{E} - e)$ or R being the total resistance,

$$\frac{i^2 \,.\, \mathrm{R}}{g} \text{ kilogrammetres.}$$

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[1] Minutes of Proceedings Inst. C.E., vol. lxxiii., p. 474.

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The object is to minimise this loss. This is to be done, supposing R constant, by making i as small as possible. This entails a high electromotive force which involves better insulation, and so increases cost. It is thus seen that the values of i and e must be so chosen as to make the cost as small as possible.

It is found that about 30 per cent. of the work is lost. This, taken in connection with the result of experiments made in the Paris workshops of the Northern Railway of France, gives

$$\frac{e}{E} = a = 0 \cdot 83.$$

If then p is the work furnished by the motor in kilograms per second

$$\frac{i^2 . R}{g} = 0 \cdot 3 \, p,$$

but $$i = \frac{E - e}{R} \text{ and } \frac{e}{E} = 0 \cdot 83,$$

therefore $$E = 10 \sqrt{p . R} \quad \text{. . . . . (1)}$$

Further, according to Uppenborn, it is best to have the internal resistance $\frac{3}{7}$ of the external resistance,

And if
$$r_1 = \text{resistance of generator,}$$
$$r_2 = \quad \text{,,} \quad \text{motor,}$$
$$r_3 = \quad \text{,,} \quad \text{conductor,}$$
$$r_1 = \frac{3}{7} (r_2 + r_3).$$

If similar machines are used for generator and motor

$$r_1 = r_2,$$

in which case $$R = r_1 + r_2 + r_3 = \frac{5}{2} r_3.$$

If 1 kilogram of conductor has a resistance of $\frac{1}{5}$ ohm, and the distance between generator and motor is l kilometres, then (allowing for two conductors),

$$r_3 = \frac{1}{5} \cdot 2 \, l = \frac{2}{5} \, l,$$

in which case $$R = \frac{5}{2} \cdot \frac{2}{5} \, l = l \text{ ohms,}$$

substituting in (1) $$E = 10 \sqrt{p . l} \quad \text{. . . . . (2)}$$

From this the electromotive force can be calculated for a line l kilometres in length, where p kilogrammetres per second must be supplied.

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For an electric railway where the motor is required to do as much work as a 300-cheval-vapeur (295·89 HP.) steam-engine on an ordinary railway,

$$p = 300 \times 75 = 15^2 \times 10^2 \text{ kilogrammetres},$$

and from (2) $E = 1{,}500 \sqrt{l}$ volts.

On a line 4 kilometres long, therefore, an electromotive force of $1{,}500 \sqrt{4} = 3{,}000$ volts would be required, a tension which could scarcely be permitted. Assuming the practical maximum at 500 volts, there would be required in a line 4 kilometres long at least $\frac{3{,}000}{500}$ = six generators and as many motors, which would be far from economical. It is for this reason that the lines at present made are only short.

In the case of an engine worked by accumulators, the weight of the accumulator was found to prevent their advantageous use on ordinary railways; in this latter case, however, the limit is the difficulty of insulation.

Name of Railway.	Length in Miles.	Greatest Inclination. Inches per Mile.	Speed. Miles per Hour.	Current in Amperes.	Total Resistance in Ohms.	Electro-motive Force in Volts.
Mödling Brühl . .	0·93	0·95	12·3	40	0·7	350
Lichterfelde . .	4·35	..	12·3	..	..	90
Beuthen	0·50	..	8·9	37	1·6	1,000
Portrush	6·21	1·58	6·9	..	1·5	500

W. B. W.

Lighting Railway Trains by Electricity.

By Gustave Richard.

(La Lumière Électrique, June 7th and 14th, 1884.)

The object of this Paper is to enumerate and describe the several ways in which it has been proposed to regulate and direct the movement of a dynamo when set in motion by power transmitted from the axles of railway-carriage wheels, so that this movement shall not be affected by the speed of the train or by the direction in which it is running. In the opinion of the Author, the easiest way to drive a dynamo, independently of the movement of the train, would no doubt be to work it by means of a

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special and separate steam-engine placed on the locomotive itself,[1] and he thinks it probable that such will be the plan ultimately adopted for lighting complete trains; but amongst the systems hitherto tried he declares his preference for those which consist in placing accumulators in the guard's van, in addition to the dynamo deriving its power from the rotation of the wheels of the van in which it is used. The Paper is illustrated by numerous drawings of the chief features of these arrangements.

When it is not proposed to use either commutators or special regulators of the current, the first condition which requires to be met is the securing a constantly uniform rotation of the dynamo, whether the train be running forward or backward. Rogers (John Banting, 1881) proposed to effect this by means of belts giving motion to the dynamo in such manner as to allow of their regulating the speed of, and, when necessary, reversing the action of the dynamo. The speed he would regulate by passing a belt over two cones, one of them inverted and standing on its apex; so that by raising or lowering it the belt is tightened or loosened on the cones. Above one of these cones, and revolving on the same axis, is a pulley-block, from which the driving-belt passes to the dynamo, and when the motion of the carriage-wheels is reversed, a ratchet shifts the position of the pulley, and gives a reversed action to the driving-belt.

Mr. Tommasi, in 1882, proposed a variety of expedients for simply interrupting the revolutions of the dynamo as soon as the motion of the train was reversed. One of these consisted in attaching to the axle of the carriage a small wheel working by friction against a second, over which the driving-belt passed, and arranged so that on the carriage ceasing to advance, or on its motion being reversed, the friction between the two wheels would cease, and the dynamo stop working. By a second plan the same effect was to be produced by the automatic action of a hammer and catch. Mr. Eli Starr of Philadelphia (1882) proposed to place one wheel on the axle of the carriage, another above it on the axis of the dynamo, and a third between the two which, when pressed against them by the admission of some of the compressed air used with a continuous brake, would cause both to revolve, but would again separate from the other wheels whenever the brake of the train came into use.

Messrs. W. H. Preece and J. James (1882) would give motion to a generating dynamo by means of compressed air continuously provided to a chamber by means of air-pumps worked by eccentrics connected with the carriage-axles; but the Author objects that

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[1] The "Times" of August 9th, 1884, contains the following announcement: "An important new departure in railway lighting is reported from the Liverpool and Manchester line of the London and North Western Co. This is the utilization of electricity for lighting the carriages by the help of a Brotherhood's patent engine stationed on the tender, and fed with steam from the locomotive boiler, locomotives being specially fitted for this service."—O. C. D. R.

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the clouds of dust raised upon the railway would choke the action of the pumps, and render such an arrangement impracticable.

He is of opinion that all the above described plans are imperfect, and that the requisite regulation of the current could be better effected electrically by using the accumulators for the purpose, or by shifting the electrical contacts, than by any mechanical contrivances. Several such arrangements have been proposed by Messrs. Stern and Billingsby, and by Mr. Tommasi and others.

One ingenious plan, devised by Messrs. Stern and Billingsby, consists in making the dynamo, on its rotation being reversed, cause the positive and negative poles of the circuit to change places; another consists in charging alternately two separate series of accumulators, and, at regular intervals, using first the one and then the other for lighting the lamps. Mr. Tommasi obtains a similar result by interposing a resistance varying with the speed at which the dynamo is running, and thus furnishing a substantially constant current to the lamps, whilst the excess only of the current passes into the auxiliary accumulators; and Mr. Calo interposes in the circuit by which the lamps are supplied, a series of accumulators which are acted upon in more or less number according as the speed of the dynamo increases or diminishes. Mr. Tommasi has also more recently advocated the use of a small auxiliary dynamo, which, when not required for keeping up the supply of a continuous and sufficient current to the lamps, should be used for maintaining a full charge in the accumulators. It is, however, pointed out by the Author that if the action of these dynamos were independent of the movement of the train, there would be no further need for any of these rather complicated arrangements, and that even the accumulators might in that case be dispensed with.

O. C. D. R.

Electricity Applied to the Boring of Tunnels.

By Aug. Guerout.

(La Lumière Électrique, vol. xiii., pp. 14–17.)

This is an article descriptive of the application, by Mr. Taverdon, of the electrical transmission of power to drive a diamond rock-drill. To fasten the diamonds in the crown, Mr. Taverdon coats them electrolytically with a thin layer of copper, and then sets them in a solder adhering to the crown-support and to the coppered diamond; the copper disappears from the active part of the diamond. The drill and the electric motor are each placed on a special carriage. The drill may be supported on the ordinary vertical pillar; it is connected to the motor carried on a trolly on rails by rope-gearing, the details of which are given. The motor

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is an octagonal Gramme dynamo. It is stated that in all the trials results have been attained equal to those of the best steam-drills, and superior in economy to those given by compressed air.

P. H.

On the Correction of Clock-Errors by means of the Telephone.

By N. K. Nordenskjöld.

(Centralblatt für Elektrotechnik, vol. vi., 1884, p. 423.)

In this Paper is described the plan, which has been in use in Helsingfors for some months, of transmitting by telephone the beats of a chronometer from the Observatory for magnetic observations, A, to the astronomical Observatory, B, for the purpose of correcting the error between the clocks at the two stations.

To one of the walls of Observatory A is fixed a small cupboard of parallelopiped form, the cover and two sides of which are of mirror-glass to produce a good resonant effect. A Hughes vertical microphone is fixed to the back of this cupboard, at the bottom of which is a Dent's chronometer mounted on gimbals, and fitted in a wooden case. The back of the case presses against two metal pins, which project a little from the face of the cupboard, carrying the microphone. By this arrangement the connection of the microphone sounding-board with the case of the chronometer is ensured. The telephonic communication between the Observatories, which are 1,342 yards apart, is established by means of a galvanized iron wire of 0·079-inch diameter, the earth being used for the return part of the circuit. The second-beats of the chronometer at station A can be heard in the telephone at station B with greater distinctness than when the ear is held only a short distance from the chronometer itself, and even the sound caused by the extension and compression of the balance spring is heard in the telephone, although this sound cannot be detected when the ear is close to the chronometer. The standard clock at Observatory B beats seconds and keeps sidereal time, whilst the chronometer at A beats half-seconds and keeps mean time. The interval, therefore, between two successive coincidences of the two clocks is 3 minutes 2½ seconds mean time, or 3 minutes 3 seconds sidereal time. The observer reads the chronometer through the glass cover of the cupboard, and as his ear detects the beats, he can, at the moment previously agreed upon, call into the telephone "Null, 1, 2, 3," &c., whilst the chronometer shows 10, 20, 30, &c., seconds. The observer, who is listening at the telephone in Observatory B, learns in this manner the exact nature of the beats he hears, and can at once make a coincidence observation, from which he is able to calculate the correction. The chronometer at A is not set, as it is used simply for regulating the two pendulum clocks for magnetic observations. An examination of the daily corrections shows that the variations per

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diem of the chronometer are much greater than the probable error due to the telephonic method of determining clock-errors.

The result of a series of trials has proved that in general only one telephonic observation is required to determine to one-hundredth of a second the difference of time between two clocks. During magnetic storms it was found possible to utilize the earth currents, and to dispense with the battery of 4 Leclanché cells usually employed. From the fact that telephones have been constructed which enable sounds to be transmitted over a distance exceeding 1,000 kilometres, the Author concludes that, with proper precautions, there will be no difficulty in sending the beats of a clock over a distance equally great, so that by the telephonic method of determining clock-errors, a simple means is at hand of finding the difference of longitude between the telegraph stations in a country, and likewise the differences between the Observatories of different countries.

J. J. W.

On the Instruments intended for Industrial Electric Measurements. By Marcel Deprez.

(La Lumière Électrique, vol. xii., 1884, pp. 3–10.)

This is an exhaustive article on various forms of instruments for measuring quantity of current and electromotive force, and it cannot be fully considered without diagrams. For a standard of quantity the Author has designed an electro-dynamometer, specially arranged to obtain the greatest mechanical effort with the least possible amount of wire. It consists of a Roberval scales or balance, in which one of the plates [pans] is replaced by a thin bobbin of large diameter. The current is led to this bobbin by spiral springs, the axis of which is parallel to the beam, so that a movement of the balance causes no change in the length of the springs. These do, however, exert a very feeble mechanical action due to the inclination of their axis, whilst the ends are forced to remain parallel; but this is not consequent of error, if the weighted index needle be caused to assume during the weighing the same position as it occupied before the passage of the current. Above and below the moving bobbin, and parallel to it, are two fixed bobbins, through which the current is so passed as to exercise a concordant action on the moving bobbin. This arrangement fulfils the given condition, because the successive elements of the fixed and moving circuits are at the least possible distance. If the current chosen as standard be passed into this apparatus, and its action be equilibrated by weights placed in the remaining pan, it is clear that this current can be exactly reproduced as often as may be required. There can here be no cause of error, because the action of the current on itself is directly measured by a weight. The action is proportional to the square

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of the current-quantity; and the Author has previously shown that, with equal density of current, the effects developed in two geometrically similar systems increase proportionally to the fourth power of the ratio of size, so that if an electro-dynamometer be constructed, having triple the dimensions of another, its effects will be, with equal density of current, eighty-one times as great. It is, therefore, easy to give these instruments only moderate dimensions, and to obtain very considerable effects. Thus the Author has constructed an instrument giving a pull of 14 kilograms with a current of 16 amperes.

Instruments of this kind should possess the following qualities: exactness and facility of reading; rapidity in the indications; simple and solid construction; indifference to foreign electric or magnetic actions; easy verification of the graduation. They should, besides, consume only a small amount of energy.

Considering the use of directing permanent magnets, and the argument generally advanced in disfavour of this class of instruments, that there is a variation of magnetic field, the Author finds that this variation is generally very small, and even when it is large the effect on the indications of the instruments is very little. To prove this, a constant current was caused to pass in a galvanometer, of which the magnetic field was constituted by a bundle of six plates, the indication of the needle was noted, and the bundle reduced to two plates, when the deflection was increased by one-third of its original value.

The Author divides these instruments into two classes: (1) those in which a portion or the whole of the electric circuit is movable; (2) those in which all portions of the circuit are fixed.

Amongst others of the first class, he has designed an apparatus composed of a core of soft iron, around which is wound a helix of silk-covered copper wire occupying about two-thirds of its length. Around this electro-magnet is put an iron tube of the same length as the core. There are thus formed at the ends of the core two annular chambers, which receive two bobbins connected together by a bar traversing the hollow core without touching it. This system of the two bobbins is suspended by two vertical wires of equal length, by which the current can enter and leave. The central core may be magnetized by a known current; the current to be measured will cause the end coils to be drawn into one end and removed from the other end of the tube, the extent of the displacement being limited by the antagonistic action of the weight tending to return the system to its original position. The amplitude of displacement being small, will be proportional to the quantity of current. The displacement can be measured and magnified by the movement of a fibre over a small pulley carrying an indicator-needle.

The Author also describes several apparatus in which the moving electrical circuit is attracted by permanent magnets, as belonging to the first class. Amongst these is an instrument in which two "recorder" frames are set on a suspended vertical rod

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at right angles to each other between two sets of permanent magnets, both bundles of these magnets having their poles in the same plane. The deflections are proportional. The apparatus of the second class includes, amongst others, chiefly variations of the well-known Deprez galvanometer, an instrument termed a "comparator." This apparatus is constructed of a fixed ring, wound similarly to the ring-armature of a Gramme dynamo. Suppose the ring divided into sixty segments, thirty are arranged on each half of the ring, and grouped so that the entering current bifurcates and determines in the two halves of the ring two poles of opposite name. Other thirty segments are similarly arranged, but so as to alternate with the first set; the diameter on which the bifurcation of the entering current occurs being at right angles with the diameter on which the bifurcation of the first set occurs. If two currents (one of which may be constant) are led into these circuits, the consequent pole in the ring will be indicated by a magnetic needle suspended in its plane; and the position of this needle will depend only on the ratio of the currents and not at all on their absolute intensity. This arrangement may be used advantageously to indicate from a distance natural phenomena, such as barometric pressure, temperature, height of water, by means of two wires, one traversed by a constant current, and the other by a current varying with the intensity of the phenomenon to be measured.

In conclusion, the Author asks the question, which amongst the several apparatus is to be preferred? The answer would be that which for equal weight of copper serving as conductor to the current to be measured, and for a given expenditure of energy ($R\,i^2$), will produce the greatest possible effect, or, in other terms, will realize the condition of a minimum of cost of static effort.

P. H.

Optical Method for Measuring the Absolute Quantity of an Electric Current. By HENRI BECQUEREL.

(La Lumière Électrique, vol. xii., 1884, p. 321.)

The Author points out the disadvantages and difficulties attending the absolute measure of a current by the ordinary means of galvanometers or electro-dynamometers, or by precipitation of silver. The method proposed is capable of the greatest precision, and consists in measuring the absolute intensity of a magnetic or electro-magnetic field by the observation of the rotation of the plane of polarization of the light traversing a body placed in this field. There may be considered a circular current of quantity i, and an indefinite right line passing through its centre and perpendicular to its plane. The sum of all the projections on this line of all the electro-magnetic actions exerted on all its points, from ∞ to $+\infty$ is independent of the radius of the circle, and

equal to $4\pi i$. If, instead of the single current, there is a bobbin comprising N turns of wire, and traversed by a current of quantity i, the sum of the actions exerted on all the points of the axis, and parallel to this axis, will be $4\pi N i$; it will depend only on the absolute number of convolutions of the wire of the coil, and on the quantity of the current. The Author arranges in the axis of the coil a tube filled with bisulphide of carbon at 0° Centigrade; a ray of polarized light is caused to traverse this tube, and the action of the current causes a rotation of the plane of polarization. If α is the rotation for the rays considered corresponding to 1 centimetre for a magnetic field equal to unity (C. G. S.), the total rotation will be $4\pi N i \alpha$. Practically the tube is limited by parallel glasses at a short distance from the ends of the bobbin. That portion of the action of the current may be neglected which, for each turn of the bobbin, is represented by $1 - \cos\omega$, as being the angle under which, from the extremity of the tube, the radius of this convolution is seen. By calculating this correction for the convolution of the last layer of the coil nearest the end of the tube, there is obtained the superior limit of the difference between the rotation observed, and that which corresponds to an infinite length of tube. If the coil is not too long, the correction for each turn of each layer is nearly the same as at the middle of the coil, because a turn in approaching one end of the tube is receding from the other. Under these conditions with a tube 3 metres in length, in the middle of which is a coil 0·50 metre long, but the external diameter of which does not exceed 0·04 metre, the corrections will not attain 0·0001. Generally so close an approximation is not needed, and an apparatus of smaller dimensions suffices, especially if the diameter of the coil is not too great. Under the conditions previously given, at 0·45 metre from the ends of the coil the error does not attain 0·001. At the ends of the tube are placed a polarimeter and an analyser mounted on a divided circle; the apparatus is lighted with the yellow rays of a sodium lamp, and the rotation R observed. The quantity of current passing in the bobbin will then be given by the relation

$$i = \frac{R}{4\pi N \alpha}.$$

That the apparatus should give absolute indications, it suffices to know exactly the number of turns of wire in the coil, and the constant α. The Author has during several years determined this number by measuring the rotation of the plane of polarization of the yellow D rays traversing a column of sulphide of carbon under the influence of terrestrial magnetism, and he has found $\alpha = 0'\cdot0463$, the number representing with a precision, comprised between $\frac{1}{100}$ and $\frac{1}{200}$, the rotation of the plane of polarization of the yellow D rays traversing 1 centimetre of sulphide of carbon at 0° Centigrade, in a magnetic field equal to unity C. G. S.

Employing a bobbin having 5,000 turns of wire, a current of

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1 ampere gives a simple rotation of 291′ for the D rays. Reversion gives from this 582′ in the opposite direction. As readings can be made to $\frac{1}{2}'$ an approximation of 0·001 ampere is obtainable. Closer approximation can be obtained by using a method of amplification of displacement of the plane of polarization of light.[1]

The sulphide of carbon has been supposed to be at 0° Centigrade. If the temperature is higher, rotation diminishes. The formula for correction as given by Mr. Bichat is

$$r = r_o (1 - 0{\cdot}00104\, t - 0{\cdot}000014\, t^1).$$

The preceding method needs no measurement of the dimensions of the apparatus. It is only necessary to have absolute measurement, to count the number of turns of a coil. The optical measurement can easily be made with great precision. Anyone can construct an absolute apparatus; a tube of 1 metre length traversing a bobbin of 0·10 metre length of 1,000 turns of wire, and the external diameter of which does not exceed 0·04 metre, forms an absolute apparatus giving a rotation of 116′ an ampere.

This method appears most practical and most exact for standardising ampere-metres. It can with proper construction be applied to very feeble or to very strong currents.

P. H.

Standard Cell for Measuring Electromotive Forces.

By Emile Reynier.

(Séances de la Société Française de Physique, July–December, 1883, p. 186.)

In this couple the negative electrode consists of a rod of zinc, amalgamated, 3 millimetres in diameter, and 100 millimetres in length (0·1 inch × 3·9 inches). The positive is of copper, a sheet having an area of 15 square decimetres (250 square inches) being pleated and bent into a cylinder, so as to surround the zinc rod, the pleats radiating outwards. These pleats are pierced or slotted down their external bends in order that circulation may be promoted, and the whole area of the plate, 30 square decimetres, be active. To this great disparity between the active surfaces of the electrodes (1 to 300), the constancy of the couple is attributed.

The electrolyte is a solution of commercial sea-salt—250 of salt to 1000 parts of water, filtered—and poured in to cover the copper cylinder. The zinc rod can be lifted out when not in use. A glass jar contains these elements. The resistance of this cell is from 0·2 to 4 ohms. Its electromotive force is 0·82 volt. Closed

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[1] Sur une nouvelle méthode d'amplification des déplacements du plan de polarisation de la lumière.—"Comptes rendus," vol. xciii., p. 143.

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through 820 ohms, its loss was $\frac{1}{100}$ of its electromotive force in two hours. Heated to 40° Centigrade (104° Fahrenheit), and cooled to 5° (41° Fahrenheit), the variation of electromotive force was quite insignificant.

Mr. Reynier invites electricians to make use of this standard.

J. J.

On the Determination of the Ohm.

By E. Mascart, F. de Nerville, and R. Benoit.

(L'Électricien, vol. vii., 1884, p. 454.)

The Authors give a short *resumé* of their experiments, undertaken for the International Commission on Electrical Units, to determine the length of the column of mercury representing the ohm. The determinations were made by the two methods, known respectively as those of Weber and Kirchhoff. In the first method a coil is suddenly rotated through 180° about a vertical axis, the plane of the coil being placed initially perpendicular to the magnetic meridian, and the induced current measured by the kick of a ballistic galvanometer placed in circuit with the coil. The resistance is then given by

$$R = 2\,S\,\frac{H}{h}\,g\,\frac{\pi}{T\,\theta};$$

where S is the effective area of the coil, H the intensity of the earth's field resolved horizontally, h the intensity of the galvanometer-field, g the constant of the galvanometer, T the period of its indefinitely small oscillations, and θ the angle of throw; all in absolute measure. The second method consists in measuring the inductive effect produced in a coil by reversing the current in a neighbouring coil. The induced current is measured in the same way by a ballistic galvanometer. If M be the coefficient of mutual induction of the two coils, I the intensity of the inducing current, then the other letters having the same significance as before:

$$R = 2\,M\,\frac{I\,g}{h}\,\frac{\pi}{\theta\,T},$$

I is determined by a tangent-galvanometer, of which the corresponding constants are h' and g', then

$$R = 2\,M\,\frac{g}{g'}\,\frac{h'}{h}\,\frac{\pi}{T\,\theta}\tan\alpha.$$

To eliminate from formula (1) the quantities H, h and g, the coil is used as the coil of a tangent-galvanometer, and a current passed

through the coil and the tangent-galvanometer, giving deflections Δ and δ. Then if G be the constant of the coil,

$$R = 2\,S\,G\,\frac{\tan\delta}{\tan\Delta}\,\frac{\pi}{T\,\theta}.$$

Similarly in formula (2) h, g, h', g', are eliminated by observing the deviations δ and δ' produced by a current passing through the ballistic-galvanometer and the coil of the tangent-galvanometer; then we have,

$$R = 2\,M\,\frac{\tan\delta}{\tan\delta'}\,\frac{\pi}{T\,\theta}\tan a.$$

The quantities S, G, and M are calculated from the dimensions of the bobbin. The calculation of M depends upon elliptic integrals, and was made according to Maxwell's method.

Employing different combinations of coils, and making use of the two methods, more than fifty series of complete observations were effected. The resistance determined was compared each time with a standard British Association unit, and the mean of the results gave,

$$\text{B. A. U.} = 0{\cdot}9861 \text{ ohm}.$$

Comparison was then made between the B. A. unit and four columns of mercury, each of 1 square millimetre section. The results showed that the ohm is represented by the resistance of a column of mercury at 0° Centigrade, 1 square millimetre in section and 1,063·3 millimetres in length.

This result was obtained by taking the mean of all the experiments without distinction. Considering the relative degree of accuracy of the several determinations the Author considers that 1,063 millimetres is a little too high.

E. H.

On the Theory of Dynamo-Electric Machines.

By Maurice Leblanc.

(La Lumière Électrique, vol. xii., 1884, pp. 161–66 and 217–221.)

The end proposed by the Author is the power to determine *à priori* what should be the constituent elements of a machine capable of furnishing a given electromotive force E when traversed by a current of quantity I, with a resistance R, and revolving with a velocity w, all previously known. It is known from the researches of Marcel Deprez that the electromotive force is proportional to the speed of rotation, and to the square root of the resistance of the conductor wound on the machine. The Author first seeks the equation to the "characteristic," in order to ascer-

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tain the relation existing between the couple dependent on the shaft of a dynamo and the current traversing the machine. This couple he finds to be proportional to the $\frac{3}{2}$ power of the current; and the characteristic is a parabola having for axis the axis of x.

As to how the electromotive force of a dynamo varies in function of the masses composing it and of their respective positions: take the case of two machines, the armatures of which are covered with the same weight of wire of the same section and turning with the same angular velocity, then the electromotive forces developed by the passage of the same quantity will be between them in a constant ratio which will depend only on the method of constructing the armatures. If there be several machines, the armatures of which are geometrically similar, and covered with a conductor of the same section, when these are traversed by currents of the same quantity, and turn with angular velocities inversely proportional to their diameters, these machines will develop electromotive forces proportional to the weights of their armatures. In two geometrically similar armatures, covered with conductors of equal section; if their linear dimensions have the ratio k, there can be developed on the shafts of these armatures the same couple by making a current traverse the larger armature, which current is of k^2 times smaller quantity than that traversing the smaller armature; that is, by expending k times less energy, because the resistance of the first is k^3 times greater than that of the second. These deductions, of course, relate to the armature only under equal excitation of the magnetic field, and under the generally occurring condition that, as stated by Marcel Deprez, in the dynamos the magnetic field is always bordering upon saturation.

The "method of similar machines," enunciated in the preceding theorems, has been followed by Edison, as the following data from the machines of this type in use at Ivry-sur-Seine will show:—

Type.	Number of Lamps.	Weight of Armature.	Weight of Electro-Magnets.	Total Weight.	Number of Turns.	Work absorbed in HP.
		kgs.	kgs.	kgs.		
E	15	108·84	226·75	334·5	2,200	3
Z	60	136·05	859·38	1,233·0	1,200	10
L	150	226·75	1,073·51	2,580·0	900	18
K	250	317·45	2,428·49	3,814·0	900	35
C	1,200	6,031·55	13,151·00	28,707·0	350	125

As to the lightest form of dynamo, the Author is of opinion that in some respects the Gramme and the Alteneck systems of winding are equally good; and passes to the consideration of the inductors, with which the end to be attained is to saturate the magnetic field where the armature revolves. This saturation may be obtained with very small quantity of current circulating around the inductors, but the result will be partly annulled by the magneti-

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zation of the ring, a phenomenon that is explained at length. His consideration of this part of the subject, however, leads the Author to believe that the efficiency of the Gramme, Siemens, and other machines may be improved by suppressing the inductors now used, and substituting large polar pieces connected by a heavy and short mass of iron without wire. Not only would the efficiency of the machine, he considers, be thus increased, but its resistance would be diminished: its power would be increased because the "characteristic" would not be flattened. At the same time weight and cost would be much diminished. The mass of iron of the armature should be much increased.

As it is the ring in any dynamo that determines the magnetic field, it is necessary that each of its halves should act as an electro-magnet under the most economical conditions. The experiments of Marcel Deprez have shown that it is best to make electro-magnets short but thick, and that the length of the core should not exceed three times the diameter. These conditions are not realizable with the ordinary type of armature, because 3 is less than π; it is then better to construct a greater number of poles in the ring, or to make the machine multipolar. In all machines the electro-magnet inductors are of absolutely independent form from that of the armature. Ordinarily they are at some distance from it, and the lines of force to which they give birth are led towards the armature by massive pole-pieces in wrought- or cast-iron. In machines of small dimensions the weight of these pole-pieces is of small importance; but in large machines, such as those of Edison, the pole-pieces become enormous blocks of metal. The greater the mass of the pole-pieces, the greater must be the mass of the iron in the inductors; and for these reasons, multipolar machines are preferable.

P. H.

A New Method of Winding Armatures in Dynamo-Electric Machines. By B. Abdank Abakanowicz.

(La Lumière Électrique, vol. xiii., 1884, p. 41.)

The Author points out that the space occupied by wire on the armature of a dynamo is not filled with the copper conductor, when the section of the wire is circular, and that the empty spaces due to the round form of the wire amount to 12·5 per cent. of the total space. The Author reviews the methods of winding with square wire and with ribands, adopted by Thomson and by Ferranti, and the suggestion of Mordey to fill the spaces left by round wire with a finer bare wire. He proposes to fill the bobbins with a flat wire or band, obtained in a peculiar way, by bending a strip of thin copper backwards and forwards, as a screen is folded on itself, then piercing the block thus formed, for inserting the core. The leaves are insulated from each other by

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bituminized paper. Each metal leaf, after being pierced, is cut through from outer to inner periphery with scissors, the cut being at top or bottom of each leaf alternately. The useless parts of the paper insulation are then removed, and the core inserted.

P. H.

Graphical Determination of the Elements involved in an Electrical Transmission by means of two Dynamo-Machines. By A. Hillairet.

(L'Électricien, vol. viii., 1884, p. 50.)

The analytical solution of this problem is usually given, but this requires a knowledge of the coefficients, which can only be deduced from the characteristics, whereas the graphical method is direct. In this method are required the curve of magnetism, or characteristic for the unit of velocity, and the curve of the intensities as a function of the moments of electro-magnetic force.

It is important to plot out the curve of magnetism for the generator from the generator-machine, and that for the motor from the motor-machine; because, in the case of the latter curve, the ordinate for the same value of I is inferior to the corresponding ordinate of the curve of magnetism for the generator.

The curve of the intensities is practically a straight line, and must for the motor be plotted out from the motor-machine.

The problem may take two forms, viz.:—

1°. The two elements of the useful effect, force and velocity being given, to find the velocity of generator.

2°. The velocity of the generator and the force to overcome being given, to find the velocity of the motor.

In the Paper, the curves of magnetism of the generator and motor, and the curves of the intensities, are shown. The Author also gives the formulas for obtaining the unknown quantity in each of the above cases.

The first form of the problem is that which would be met with most frequently in practice; but the Author cites an example, which requires the application of the formulas appertaining to the second form.

J. J. W.

The Electrical Units and Unit of Light adopted by the Paris International Conference. By Dr. Werner Siemens.

(Electrotechnische Zeitschrift, vol. v., 1884, p. 244.)

The latest determinations of the ohm did not fulfil the stipulation formulated by the delegates who took part in the Paris Conference of 1882. This stipulation was that the evaluations of the ratio of the ohm to the mercury unit should not differ from

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one another by more than one-thousandth part. The Committee finally decided that, pending the results of a further series of more exact experiments, the value of the legal ohm should be taken as equal to 1·06 mercury-unit.

The Author remarks that as soon as the C. G. S. system of electrical units is legally established, the special designations, volt, ampere, coulomb, farad, adopted by the Conference for the unit of electromotive force, current strength, quantity and capacity will be superfluous. Each unit will then be distinguished by its numerical value, and a special name or symbol will be needed only for such units as do not form part of the C. G. S. system. For instance, resistance-measurements obtained by means of the mercury-unit may be expressed by attaching the symbol "Hg" to the numerical results to indicate the unit employed.

As soon as the final evaluation of the units has been made, standards will have to be constructed, and a practical method of reproducing them will also have to be worked out. The Author expresses a hope that no time may be lost in the prosecution of this work, so that science will soon have at command a concordant and practical system of electrical measures.

The unit of white light adopted by the Conference is the quantity of light emitted by 1 square centimetre (0·155 square inch) of pure molten platinum when at the temperature of solidification, and the unit of coloured light, the quantity of light of the same colour as that to be measured contained in the white light given out by the platinum.

The Author has devised a small instrument by means of which the standard unit of light can be produced at any moment. In a small metal-box mounted on a short column are contained a bobbin, on which a strip of platinum foil 5 to 6 millimetres wide (0·196 to 0·236 inch) and about 0·02 millimetre (0·0008 inch) thick is wound, and a bent spring lever ending in a small clip which holds the free end of the platinum foil. To the lever is attached a small metal rod, which passes through one end of the box. When the rod is pushed inwards the end of the foil is released, but on inserting the foil in the clip and allowing the rod to spring outwards the foil is held firmly in the desired position. In one of the side plates of the box is a conical hole, the smaller end being on the inner face of the plate. The cross-section of this part of the hole measures exactly $\frac{1}{10}$th of a square centimetre (0·016 square inch). The platinum foil is held immediately behind the hole, so as to cover it entirely. When the foil is brought to a white heat by passing the current of a few battery-cells through it, the quantity of light passing through the hole is practically the same as if the surface of the platinum coincided with the plane of the smaller part of the orifice. The strength of the battery current can be gradually increased until the foil melts, and the light, when measured at the moment immediately preceding its extinction, is exactly one-tenth of that of the unit of white light adopted by the Conference.

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By means of this apparatus the unit of light can be produced in a serviceable, practical form, and how far it will become available for the direct measurement of light will be soon ascertained in practice.

The Author points out that in his apparatus the quantity of light emitted by the platinum at its melting point is taken as the standard, whereas the legal unit is defined to be the quantity of light given out by the molten metal when at the solidifying point. It has not yet been determined whether a difference of temperature exists between the points of fusion and solidification of pure platinum. If a difference should be found, the results obtained with the Author's apparatus would have to be corrected by means of a suitable coefficient.

J. J. W.

An Absolute Unit of Light. By — Violle.

(Read before the Société technique de l'Industrie du Gaz, and printed in the Journal des Usines à Gaz, 5th July, 1884.)

Among the many difficulties of photometry, the first is the choice of a suitable standard. Candles are employed in England and Germany, and the Carcel lamp is used in France. For candles it is difficult to obtain a substance of uniform composition; stearine varies, sperm or paraffin are better—but uniformity cannot be relied upon; paraffin candles have been found by Mr. Monnier not to vary more than 4 per cent. in illuminating power, while sperm candles vary as much as 15 per cent. The wicks are also a further drawback in candles; the liquefied matter reaches the flame by capillary attraction, and this action depends on the size and texture of the wick, which may vary at different parts of the same candle, and still more so in different candles; also the more or less curved position assumed by the wick in burning affects the illuminating power.

The Carcel lamp is preferable to candles, as, although the Colza oil is not always identical in composition, the influence exercised by the wick is diminished, the oil being forced up it mechanically in such quantities that it is constantly full, and the wick is consumed very slowly.

Attempts have also been made in France and England to utilize an ordinary gas-flame under suitable conditions for the standard, and Mr. Vernon-Harcourt has proposed the vapour of pentane for the same purpose; but to obtain an absolute standard it is not sufficient to have a material of constant composition burning always in the same manner, the flame also must be always identical, and consequently the air-supply, as well as the gas or other material, must be identical in composition. It is well known that flames are affected by any change in the condition of the atmosphere, and a Carcel lamp burning in a small apartment occupied

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by a number of persons, will quickly change from its normal condition of burning. Again, the intensity of any luminous body depends upon the temperature, and the illuminating power increases much more rapidly than the temperature. Taking the illuminating power of platinum at the point of fusion at 1, the following are the proportions:—

Temperatures.		Intensities.
775° Cent.		0·00007
954° „	(melting point of silver)	0·0012
1045° „	(„ „ gold)	0·0045
1500° „	(„ „ palladium)	0·271
1775° „	(„ „ platinum)	1·000

The higher the temperature of a source of light, the more difficult it becomes to maintain it constant, and the more necessary it is to do so. With a flame, it is difficult to keep the temperature constant; it is also transparent, and, all other things being equal, the quantity of light emitted varies with the transparency.

Many of these objections are avoided with an incandescent solid, and it might be supposed that an incandescent electric light, supplied with a definite current, would furnish an absolute photometric standard; but if platinum wire is employed for the lamp, it breaks spontaneously after a current has been passed through it for some days, and constant modifications are produced in the wire, causing variations in the resistance, and consequently changes of temperature. Incandescent lamps with carbon filaments are free from some of these defects, but not from all; according to the nature of the carbon, the electric energy is divided into calorific energy and lighting energy, and this division varies with different lamps.

At the International Electrical Congress of 1881, Mr. Violle proposed platinum at its point of fusion as an absolute unit of light. The fusing point of any metal is invariable, so long as some solid portions remain with the melted portions, and if an unchangeable metal, such as platinum, is used, it will always give out the same amount of light from a given surface, the quality depending upon the temperature.

The furnace of Messrs. Sainte-Claire Deville and Debray is the most convenient for maintaining a fixed surface of platinum constantly at fusing point. It consists of a piece of lime with a cavity in it for the reception of the platinum, provided with a cover of lime and fitted with an oxy-hydrogen blow-pipe. Heat is at first applied gradually, and increased until the platinum begins to melt. When melted and raised even to a temperature exceeding its point of fusion, it is placed under a diaphragm having an aperture of a determined area. The exact dimensions of the aperture may be ensured by having the diaphragm double with a space between the surfaces, and a current of water flowing through. Such a diaphragm may be exposed to the blow-pipe flame without melting the platinum, and without raising the temperature of the water more than a few degrees. The rays

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passing through the aperture are received upon the photometer-screen, protected from all external radiation. The screen may be fixed horizontally above the platinum, or, as is more generally the case, it may be vertical, and the light from the platinum reflected by a mirror or rectangular prism at 45°. In the latter case, the coefficient of absorption of the mirror or prism must first be determined.

The rays from the platinum, and those from the light to be examined, being both projected on the photometer-disk, they are made to agree in intensity. The intensity of the fluid platinum is not permanent; as it cools, its light diminishes rapidly; it falls quickly at first, then more slowly, and becomes stationary at a certain point, remaining so during its change from fluid to solid, and when solidified, a further falling off of its light intensity commences. The observations should be made during the constant period; at first sight this may seem difficult, but with the application of a small amount of heat, the platinum may be maintained in a semi-fluid state for any required time, the solidification of the platinum is also accompanied by a flash of light which indicates the termination of the constant period.

The entire process presents no serious difficulty, particularly as it is proposed for use only as a standard of reference for verifying other standards in ordinary use.

Two experiments were made for estimating the value of the light from a Carcel lamp, compared with the platinum standard, 1st. By comparison with direct radiation from the platinum at an angle of 45°; and 2nd. By comparison with the radiation from the platinum reflected horizontally on a mirror at 45°. The surface of the metal experimented with had an area of 3·96 square centimetres; its distance from the photometer-screen was 3,204 millimetres and assuming the normal dimensions of the Carcel-lamp flame to be 35 millimetres high, and 15 millimetres wide, it was found, from a number of trials, that an equal surface of platinum would give out a light equal to 10·92 Carcels. The intrinsic intensity of the standard was therefore about eleven times that of the Carcel lamp.

C. G.

The Form of the Iron Core in Arc-Lamps.

By Prof. Dr. Dietrich.

(Centralblatt für Elektrotechnik, vol. vi., 1884, p. 485.)

The result of some experiments of Dr. Boettcher showing that the form of the iron core in the solenoid of an arc-lamp was immaterial, and it might be conical or cylindrical, led the Author to investigate what form of core would serve best for regulating single arc-lamps with one solenoid in the main circuit, and what would be the effect of using conical in place of cylindrical cores

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for lamps with two solenoids. The investigation applies only to differential arc-lamps of the Pilsen type, that is, to those without clockwork or releasing gear. In a Jaspar lamp, for example, there are various forces acting on the carbons, viz., those resulting from the attraction of the solenoid, the weight of the carbons and their holders, the weight of the core and the variable pull on the circumference of the roller carrying the cord and weight, the changes in this latter force being due to the burning away of the carbon rods. The Author includes all the mechanical forces under one term, "the opposing force," and the attraction of the solenoid is designated "the attractive force." These two forces can be determined for each construction of lamp, and they may be expressed as functions of the distance between the middle of the core and the solenoid. In the graphical delineation of the two forces this distance is plotted out on the line of the abscissas. The result of the Author's theoretical analysis is, that in each position of the core of a lamp with one solenoid in the main circuit, the attractive force due to the normal current-strength must be equal to the opposing force, that is, the curves of these two forces must be identical, and it is only under these conditions that the arc length of such a lamp will remain constant from the time the carbons begin to burn until the lamp is put out. The Jaspar lamp fulfils the theoretical conditions in a measure, but the Author points out, that the curves of the two forces for this lamp would have been more concordant, had an arrangement been adopted by which the weight acting on the circumference of the roller could, in the course of its movement, have been held at a variable distance from the axis of rotation. For instance, the weight might have been suspended from a cord, which could have wound itself on an eccentric disk of suitable form. The curve of the attractive force shows that the form of this excenter would be an exceedingly simple one. There is no doubt that a certain form might be found for the iron core, which would require as opposing force only the weight of the carbon-holders, and that of the carbons during their gradual consumption, so that all mechanical accessories for the production of this force, such as springs, &c., would be superfluous. In this case the curve of the attractive force would become a straight line running almost parallel with the abscissal axis. The conical form of core does not, however, fulfil this condition; the solution, therefore, to the first problem of the investigation is, that for single lamps with one solenoid in the main circuit the form of the core is unimportant. A similar investigation might be applied to shunt-lamps with one solenoid. As regards the second part of the investigation, the Author gives some results obtained with a differential lamp of the Pilsen type, with two separate cores as made by Schuckert. When a number of these lamps are in a circuit, and the regulation is such that the length of arc remains constant at each stage of consumption of the carbons, the current passing through the main and shunt-coils must also be constant. In this case there is a definite curve of

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attraction for the main coil due to the normal current flowing through it, and the mechanical opposing force of the single solenoid lamps is replaced by the curve of attraction due to the constant current in the shunt-coil. In each position of the core the attractive and opposing forces must be equal; it is therefore evident that the curves due to the attractive forces of the two solenoids must be identical, and on their abscissas are the distances between the middle of the cores and solenoids. The Author shows that with cylindrical cores the curves of attraction for the main and shunt-coils are far from being identical, and points out that to obtain a satisfactory regulation of the lamps, when the cores are in various positions, it would be necessary to supplement the two electrical forces by a mechanical one, such as the eccentrically-shaped disk proposed for the single solenoid lamp. When conical cores are used in place of cylindrical ones the curves of attraction are more concordant, but an equality of these curves as soon as the distance between the middle of the core and coil becomes considerable cannot be attained.

J. J. W.

Resistance of the Carbons employed in Electric Lighthouses.

By F. Lucas.

(Comptes rendus de l'Académie des Sciences, Paris, vol. xcviii., 1884, p. 800.)

The Carré carbons employed in the French lighthouses are 0·016 metre in diameter, as used for the ordinary lights, and 0·024 metre for the "double" lights used when there are fogs. The resistance at 15° Centigrade is, as nearly as may be estimated from a large number of bridge-measurements, 70 ohms per square millimetre of section and per metre length, but the differences from this average amount to as much as 30 per cent. The Author has made experiments to ascertain how these carbons vary in resistance with the quantity of electric current. The results led to the empirical formula

$$y = y_o\left(1 - \frac{\mathrm{I}}{25 \text{ amperes} + 1\cdot 2\ \mathrm{I}}\right),$$

y_o being the resistance at 15° Centigrade, and the quantity of current I varying from 50 to 142 amperes, when the coefficient of y_o diminished from one-third to one-fourth.

Further measurements as to the variation of temperature led to the formula

$$\mathrm{T} - 15^\circ = \frac{\mathrm{I}}{0\cdot 112 \text{ ampere} + 0\cdot 0004\ \mathrm{I}};$$

and $y = y_o \dfrac{1 + 0\cdot 0005\ (\mathrm{T} - 15)}{1 + 0\cdot 0005\ (\mathrm{T} - 15)}$, which may be applied for temperatures between 400° Centigrade and 900° Centigrade.

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Putting $\Theta = T - 15°$, the number of calories disengaged per second is—

$$K = \frac{y\,I^2}{4{,}154} = \frac{0 \cdot 0477\,\Theta^2 + 0 \cdot 000024\,\Theta^3}{104{,}000 + 434\,\Theta - 0 \cdot 397\,\Theta^2 + 0 \cdot 000083\,\Theta^3}.$$

The cooling surface for a cylinder of 0·016 metre diameter, and 0·400 metre length, being approximately 20,000 square millimetres, $\frac{K}{20{,}000}$ gives the fraction of a calorie disengaged per square millimetre of surface for each value of Θ.

P. H.

Lighting Madrid by Electricity.

(La Lumière Électrique, June 7, 1884.)

It has been decided to light the city of Madrid from a large central station which is to be erected on a piece of ground between 16,000 and 18,000 feet square near the gate of Salamanca. The steam-engines, dynamos, and workshops will occupy the ground floor of the building, and the floors above will be laid out in offices, stores, and apartments for the servants of the company. There are to be fifteen steam-engines, each of 100 HP., and eight of 250 HP., with two powerful dynamo machines, calculated, when making one hundred and fifty revolutions per minute, to generate 10,000 amperes of current, with an electromotive force of 120 volts. The main conducting wires are to be all underground, to be made of the purest copper, and, in order to provide against heating of the wires, their section is to be regulated at the rate of 1 square millimètre for every three amperes of current.

O. C. D. R.

The Influence of Light on the Electrical Resistance of Metals.

By Arthur E. Bostwick.

(The American Journal of Science, vol. xxviii., August 1884, p. 133.)

The influence of light on the electrical resistance of selenium has been investigated by W. G. Adams, Werner Siemens, and Sir William Siemens. It has also been shown that tellurium possesses the same qualities in this respect as selenium, though in a much less degree. Adams found the greatest diminution of resistance in tellurium to be 0·33 per cent. In 1877 Börnstein published a Paper, in which he attempted to show that other metals, such as gold, silver, and platinum, possessed similar properties; but subsequently Werner Siemens and Hansemann concluded, from an elaborate series of experiments, that there was no action in the case of these latter metals. In 1881 Börnstein published a new

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series of experiments, from which it would appear that the electrical resistance of silver was diminished 0·0125 per cent. by the action of light.

Börnstein's first experiments were made upon platinum wires and thin leaves of gold, silver, and platinum, mounted on glass. Two methods were employed. The first consisted in the comparison of the resistance of two wires or plates, alternately illuminated. The second consisted in the observation of the logarithmic decrement of the swing of a galvanometer needle, the galvanometer being coupled in circuit with a single plate, which was alternately illuminated and darkened. The results obtained by the two methods varied very considerably. The later experiments of Börnstein were made entirely upon silver chemically deposited on glass, and consisted in the direct measurement of the ratio of the resistances of two plates by means of a Wheatstone bridge, with sliding contact wire. The plates were exposed to the light for a period of fifteen minutes.

Werner Siemens and Hansemann in their experiments made no direct measurements, but noted merely the slight changes of position of the index of a sensitive galvanometer, coupled either in a Wheatstone bridge, or in circuit with a source of electricity and the metal plate to be examined, the plate being illuminated and darkened at short intervals.

In the Author's experiments, carried out in the laboratory of Yale College, five plates, A, B, C, D, E, were employed. The plates A and B were of silver, deposited on plate glass, in a film thick enough to transmit about 50 per cent. of light; C, D, and E were of platinum, gold, and silver, respectively, deposited on glass in vacuo, and also each thin enough to transmit light easily. The observations were made to determine, first, the instantaneous effect of light, and secondly, the effect of exposure for from ten to fifteen minutes. Two methods of experiments were used, viz., the Wheatstone bridge method, in which one arm was formed by a single plate, and a similar method in which two arms of the bridge were formed by the plates A and B, which were then exposed to light alternately. The results are summed up in the following Table:—

INSTANTANEOUS EFFECT. (METHOD I.)

Plate A.	Increase of a few thousandths of	1·00	per cent.
„ B.	No diminution of more than	0·001	„
„ B.	(Sunlight). Increase of	0·004	„
„ C.	Increase of	0·0002	„
„ D.	Increase of	0·0003	„
„ E.	Increase of	0·00005	„

LONG EXPOSURES. (METHOD II.)

A and B.	Mean effect on plate illuminated—Decrease of	0·0014	per cent.
A′ „ B′.	„ „ „ Increase of	0·0053	„

	Mean effect of Illuminating the plate.	Mean effect of Darkening the plate.
C.	Increase of 0·004 per cent.	Increase of 0·0016 per cent.
D.	Decrease of 0·003 „	Decrease of 0·014 „
E.	Increase of 0·005 „	Increase of 0·007 „

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These results are more in agreement with those of Siemens and Hansemann than with those of Börnstein, and show that if light causes any diminution in the electrical resistance of the metals experimented on, it probably does not exceed a few thousandths of 1 per cent.

E. H.

The Electro-chemical Equivalent of Silver.

By F. and W. KOHLRAUSCH.

(Exner's Repertorium der Physik, vol. xx., part 4, 1884, p. 260.)

The Authors record in this Paper the results of a determination of the electro-chemical equivalent of silver, which probably attains an exceedingly high degree of accuracy. Two series of experiments were made by the Authors independently, with different apparatus, and at different times, and to some extent by different methods. In both series the current was measured by a tangent galvanometer, but the strength of the magnetic field was determined by three distinct methods, viz., Gauss's method of oscillation and deflection, and the methods of the absolute bifilar galvanometer and bifilar magnetometer.

The electrolyte employed was nitrate of silver, the duration of the electrolysis from thirty to fifty minutes, and the intensity of current between 0·2 and 0·5 ampere, and the silver deposit between 0·5 and 1·3 gram. The results of four series of experiments by the first method gave 1·1187, 1·1180, 1·1177, 1·1181, and 1·1182, giving a mean 1·1181, as the quantity of silver in milligrams deposited by a coulomb of electricity. Four series of experiments by the second and third methods gave the numbers 1·1184, 1·1185, 1·1186, and 1·1183, of which the mean is 1·1184. Taking the mean of this and the previous, the final result is 1·1183 milligram per coulomb. The corresponding equivalent for copper is 0·3281 milligram per coulomb.

E. H.

On the Generation of Electricity by the Filtration of Mercury.

By J. DECHANT.

(Centralblatt für Elecktrotechnik, vol. vi., 1884, p. 522.)

Pfaundler's apparatus for filtering mercury consists of an iron tube about 45 centimetres (18 inches long), to one end of which a glass funnel is cemented, the other end being closed by a piece of chamois leather fastened round the tube by a screw clip.

While emptying a glass dish containing mercury which had been passed through a Pfaundler filter, the Author received a smart electric shock when by accident a finger of the hand

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holding the dish came in contact with the mercury as it ran out. Some mercury was then filtered into an insulated iron vessel and the electrification found to be positive; by using an iron dish in place of a glass one, no electricity could be generated through the contact of glass and mercury. It was evident therefore that the production of electricity was due to the friction of the mercury in the fine pores of the leather.

When the filtered mercury was collected in a glass dish coated outside with tinfoil, so as to form a Leyden jar, bright, crackling sparks could be drawn from it. The quantity of electricity generated depends on the porosity of the leather through which the mercury is filtered. The Author found that leather prepared from the head and leg portions of the skin of a chamois or sheep was of very close texture, and gave the best results.

J. J. W.

Hall's Phenomenon. By A. LEDUC.

(Comptes rendus de l'Académie des Sciences, vol. xcviii., 1884, p. 673.)

If there is placed between the poles of a powerful electromagnet, and perpendicular to the lines of magnetic force, a very thin metallic plate traversed by a current, there is developed in this plate a transversal electromotive force, which Mr. Hall considers due to a pressure sustained by the current. Mr. Righi has found that the effect is much greater in bismuth than in the other metals hitherto studied. The Author now announces that he finds that the transversal electromotive depends on the quantity of current that traverses the plate; on its temperature; on the mean magnetic intensity in the space that it occupies in the field. This is true for bismuth. For silver there is a deflection of the lines of equipotential dependent on the temperature. If the magnetic intensity does not exceed a certain value, the deflection of the line of equipotential and of the lines of force at the points where they intersect is represented by $D = k\,M\,(1 - a\,t)$, k being the deflection produced at the temperature 0° at a point where the magnetic intensity is equal to 1. a is another constant, and for bismuth is very small; for silver it varies from 0·008 to 0·009. This deflection may be considered due to the heterotropy that the metal takes in the magnetic field analogous to that sustained by light in falling normally on a bi-refracting substance.

The phenomenon is very feeble in an alloy of bismuth and lead (equal weights); and, according to Mr. Hall, it is nil in lead. The crystalline state of bismuth, therefore, appears to play a great part in the production of the phenomenon.

P. H.

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On the Phenomenon of the "Transport of Ions" and its relation with the Conductivity of Saline Solutions.

By E. Bouty.

(Comptes rendus de l'Académie des Sciences, Paris, vol. xcviii., 1884, p. 797.)

This is a continuation of the subject studied in two previous notes. The Author designates as normal electrolysis that simple action involving the liberation of equivalents of the electrolyte that can be easily recognized, as in a voltameter with well-separated electrodes, the electrolyte being a solution of sulphate of potash. If, on the contrary, the solution is one of nitrate of soda, the liquid is impoverished progressively around the negative pole, and when an equivalent of salt has been decomposed, the loss of concentration at the negative pole corresponds to 0·614 of an equivalent, and at the positive pole to 0·386 only. Hittorf termed these numbers "carrying" numbers, and gave their value for a large number of salts. The Author examines these numbers for various concentrations of solution, and finds them represented by 0·5 for $\frac{1}{200}$ to $\frac{1}{1000}$ concentrations.

P. H.

Note on the Application of Electricity to Michela's Stenographic Apparatus. By L. Chenut.

(L'Électricien, vol. viii., 1884, pp. 97–146.)

In a quarter of an hour's work an ordinary stenographer cannot write more than one hundred and twenty words in each minute, and the rate of speaking of different orators varies from eighty to one hundred and eighty words per minute. By means of the apparatus described in the Paper, an operator can stenograph two hundred words a minute without fatigue.

After long and patient study Mr. A. Michela succeeded in grouping together all the phonetic sounds belonging to any language, and representing them by means of various combinations and signs. His stenographic apparatus imprints the characters corresponding to the sounds on a paper ribbon, which is moved forward automatically by special mechanism. The printing is effected by working a key-board consisting of twenty keys, the lever of each being connected with a vertical rod, which carries at the end lying beneath the paper band a stenographic sign in relief.

The electrical transmission to a distance of a speech at the moment it is being delivered has been successfully carried out, and Mr. Cassagnes, in a communication made by him to the Société d'Encouragement on the 11th of March, 1881, cited this as an

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achievement which it might be possible to accomplish at some future time by means of Michela's stenographic apparatus.

The mechanism described by the Author is in its essential features similar to that of a Morse ink-writer. Its office at the receiving station is to imprint on a paper band, which is moved forward by suitable feeding-gear, the stenographic signs corresponding to the twenty keys forming the key-board at the sending station. Each of these keys when depressed closes a circuit formed by an insulated wire, an electro-magnet at the receiving station, the earth or a return wire and a galvanic-battery. The armature of each electro-magnet carries a marking lever bearing on its end face the stenographic character to be imprinted on the upper, the necessary distinctness being attained by causing the lever in its upward movement to press an inking-tape against the paper band. The entire arrangement of the stenographic apparatus may be regarded as twenty Morse instruments specially devised for the telegraphic transmission of stenographic characters, the result being a speed of working far superior to that of any other system of telegraphy.

The Author gives the following Table, showing the average working speed of different instruments:—

					Words.
Ordinary Morse,	25	messages of 20 words	each	per hour	500
Hughes,	60	,,	,,	,,	1,200
Meyer, with keyboard,	25	,,	,,	,,	500
Baudot ,,	40	,,	,,	,,	800
Wheatstone,	90	,,	,,	,,	1,800
Ordinary mirror,	30	,,	,,	,,	600
Gray's harmonic					700
Stenotelegraphic, with keyboard					10,000

The principal outlay in establishing a system of stenotelegraphy would be for the cable, and the cost of one composed of twenty or twenty-one insulated wires would, with the laying, be considerable; but with a working-day of ten hours one hundred thousand words can be transmitted, so that the receipts in one year would very nearly cover the cost of a cable between Paris and Brussels, that is, one of 400 kilometres (248·55 miles) long.

The Author points out that, by applying the principles of multiple telegraphy to the apparatus, the number of wires might be reduced one-half, and by the use of polarized relays only twelve wires would be required in place of twenty.

For Parliamentary work the stenotelegraphic apparatus would prove invaluable. The key-board could be placed in the reporters gallery, and the receiving instrument in the newspaper office, where compositors, trained in reading the slip, could at once set up the required type.

J. J. W.

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On the Commercial Production of Oxygen and Hydrogen.

By Messrs. Brin Brothers.

(La Nature, 23 August, 1884, p. 179.)

From time to time attempts have been made to render the abstraction of oxygen from the air, by aid of the monoxide of barium, commercially successful. These attempts failed through a gradual enfeeblement, with use, in the absorptive power of that salt. The Authors have succeeded, after many experiments, in producing baryta, which, so far from falling off in productiveness, improves up to a certain point, and then retains its powers indefinitely. A yield of 50 litres of oxygen per kilogram (0·8 cubic foot per lb.), may be obtained without pushing the deoxidation too far.

The baryta produced by their process is placed in horizontal retorts, which for peroxidation are heated to a temperature of between 500° and 600° (about 1,000° Fahrenheit). For decomposition the temperature is raised to 800° (1,472° Fahrenheit); these temperatures being automatically regulated.

Two pumps are in connection with the retorts; one for supplying air, the other for the subsequent withdrawal of oxygen. The air is treated for the removal of carbonic acid before pumping, and the purity of the oxygen thus ensured.

It is proposed to utilize the nitrogen obtained in the process for the production of ammonia, by mixing it with the vapour of water at a temperature of 150° Centigrade (302° Fahrenheit), in presence of baryta and carbon; these substances, absorbing the oxygen of the decomposed water, leave the hydrogen to combine with the nitrogen.

J. J.

On the Temperature of Ignition of Gaseous Mixtures.

By Messrs. Mallard and Le Chatelier.

(Annales des Mines, vol. iv., 1883, p. 274.)

In their experiments the Authors used, preferably, a closed chamber, raised to the required temperature by heat externally applied. Into this chamber, previously rendered vacuous, the explosive mixture of gases was suddenly admitted; a series of experiments at different temperatures giving a close approximation to the true temperature of ignition.

The gases investigated consisted of mixtures of hydrogen and oxygen; carbon monoxide and oxygen, and fire-damp and oxygen. For these, ignition-temperatures of 555° C. (1,031° Fahrenheit); 655° C. (1,211° Fahrenheit), and 650° C. (1,202° Fahrenheit), were respectively obtained. Such results were found to be independent both of the presence of an inert gas, such as nitrogen, or of the

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proportions in which the explosive gases were mixed. It was noticed, however, as an exception, that the addition of a large quantity of CO_2 elevated the ignition-temperature of a mixture of CO and O from 655° to 700° (1,292° Fahrenheit).

It was long ago ascertained by Davy that slow combustion, without evolution of light, occurred when such gaseous mixtures were exposed for some time to a temperature considerably below that of ignition. The experiments of the Authors showed that there is discontinuity between the phenomenon of slow and that of sudden combustion; *i.e.*, that the rapidity of combustion is not increased proportionately to the elevation of temperature, but remains feeble till the ignition point is reached. An explanation, based on the mechanical theory of gases, is advanced by the Authors.

For mixtures of H and CO with oxygen, combustion ensues immediately on exposure to the temperature of ignition. In the case of fire-damp and oxygen, however, it was remarkable that ignition did not occur often till ten seconds after the mixture had been raised to or above the temperature of ignition. This retardation of ignition, the Authors suggest, may be the result of indirect combination. The retardation was more marked as the temperature was lower, and as the quantity of inert gas present was increased.

At the temperature of 1,000° (1,832° Fahrenheit), this retardation vanishes; and Davy, experimentally introducing a heated iron into the mixture, concluded that this temperature was that of ignition. This was an error. The Authors found that, if the circulation of the gas over the heated surface was retarded so that the gas remained for some time in contact with the source of heat, ignition ensued at much lower temperatures.

The Authors point out that in fiery coal-mines, an incandescent body, if freely exposed, is thus not necessarily sufficient to cause explosion.

J. J.

On the Temperatures of Combustion and Specific Heats of Gases at High Temperatures. By Messrs. Mallard and Le Chatelier.

(Annales des Mines, vol. iv., 1883, pp. 379–559.)

The Authors show in the first instance that the pressure produced during the combustion of a gaseous mixture are greater than the static pressure, which would result from the expansion due to the temperature of combustion, the increase of pressure concentrating its action within section to section before affecting the whole mass; they next obtained graphic representations, by means of continuous curves, of the law of the variation with the time of the pressure of a mass of gas burnt within a closed space, from the moment of ignition in the centre of the mass,

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until the burnt gas returns to the temperature of surrounding space.

The memoir may be considered under the following sections:—

Law of cooling of Gases.—With permanent gases, that is, gases which do not condense during cooling, the velocity of cooling is represented by the expressions

$$\frac{d\,\theta}{d\,t} = a\,\epsilon + b\,\epsilon^2,$$

in which ϵ is the excess of τ over τ_0, τ being the absolute temperature of the gas (in some cases as high as 4,000° Centigrade absolute), and τ_0 that of the atmosphere. The coefficients a and b do not vary much for the different permanent gases CO^2, O, N and CO. The coefficient a appears to be independent of the pressure; the coefficient b diminishes as the density of the gas increases, and *vice versâ*. The same formula is applicable when a small quantity of vapour is added to the gas (the cooling influence of the gas being preponderant), but the coefficients have different values in this case. With vapours the law of the fall of pressure is represented by the expression

$$\frac{d\,w}{d\,t} = a\,(w - p_0),$$

w being the variable pressure, and p_0 the tension of the vapour at the temperature of the atmosphere. When a small quantity of gas is mixed with a large quantity of vapour, the fall of pressure is given by the expression

$$\log. \frac{1}{w - p_0}\,\frac{d\,w}{d\,t} = a\,(w - p_0) + b\,(w - p_0)^2.$$

Dissociation.—The continuous curves before referred to prove that when a mass of carbonic acid, raised to the temperature of combustion, cools in a closed space, the dissociation, which commenced at the moment of combustion, diminishes with the recombination of the elements, until the mean temperature of the gases is about 1,800°; this is so when the density of the CO_2 is such that it exerts a pressure of 50 centimetres of mercury at the temperature of 15°; the mean temperature of the gas at which dissociation ceases diminishes with the pressure, being 1,600° when this is 28 centimetres, and only 1,160° when it is 13 centimetres. When CO, O, or N are mixed with CO_2, the effect is the same as diminishing the pressure of the CO_2, being most marked with N, and next so with O. The Authors observed little or no dissociation with water-vapour, which they account for by its great velocity of condensation; at 3,300° the temperature of combustion of H_2 and O, there was very weak dissociation; this was also the case with CO between 3,000° and 4,000°.

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Temperatures of combustion at constant volume.—By applying the data acquired by the law of cooling, for making the necessary corrections, the pressures produced by combustion have been determined, and the temperatures of combustion when there has been no dissociation have been deduced. The Authors give a table of temperatures for various combinations, from among which may be taken CO+O 3,130°, with 0·61 of the gas combined; CO+O, with various additions of CO_2 and N, from 1,980° to 1,670°; $H_2 + O$ 3,350°; $H_2 + O$, with various additions of CO_2, O and N from 2,830° to 1,300°; CH_4, with various additions of O and N, from 2,150° to 1,660°. These temperatures are for combustion in a closed vessel; ordinary temperatures of combustion are those of a gaseous mixture expanding when burning under constant pressure.

Specific heats of Gases.—When a gaseous mixture burns without dissociation, a simple equation connects the heat and temperature of combustion with the mean specific heat between this temperature and zero of the gases existing after combustion. The heat of combustion being given by the experiments of Mr. Berthelot, and the temperatures of combustion by these experiments, the Authors have thence deduced the mean specific heats. In the case of carbonic acid, they added various quantities of CO_2 to CO and O, so that the gaseous products might be CO_2 only, and thus obtained 13·6[1] as the mean specific heat of CO_2 at or about 2,000° Centigrade. In combining this with the specific heat at 0, and between 0° and 200°, as obtained by Regnault, the following formula is obtained:—

$$C_v = 4 \cdot 33 \, (\tau \cdot 10^{-2})\, 0 \cdot 367.$$

This formula is nearly equivalent to the more simple one,

$$C_v = 4 \cdot 74 \sqrt[3]{\tau} \cdot 10^{-2}.$$

The Authors have preferred these exponential formulas to a parabolic one they also tested, which seemed to give improbable results at and above 2,500°. They obtained no dissociation with water-vapour up to 3,350°, and have deduced from their experiments the formula

$$C_v = 5 \cdot 61 + 3 \cdot 28\, t \cdot 10^{-3}.$$

They find that the specific heat of a combination of CO_2 and HO_2 give concordant results with those obtained from these gases separately. As regards perfect gases, they have deduced the following law from their experiments:—The molecular specific

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[1] The specific heat has reference in each case not to a gram weight, but to the molecular weight, *i.e.*, the weight of gas which occupies 22·32 litres; this volume is that occupied by 2 grams of H at 0° Centigrade and 760 millimetres pressure.

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heats of perfect gases, which are equal at ordinary temperatures, continue so at temperatures at and perhaps above 3,000°. The invariability of the specific heat having been established by Regnault for temperatures up to 200°, and confirmed by Wiedemann, had been considered as a fundamental character of perfect gases, although not supported by any theoretical principle. There was added to a mixture of CO and O variable quantities of N, O, and CO, and the specific heat of CO_2, having been already determined, it was found that those of the perfect gases rose from 4·8 to 7 at 2,000°; but as in such mixtures it is not certain that dissociation does not occur, the same experiments were repeated, when H_2 and O were used, in place of CO and O, with the same results. The conclusion at which the Authors arrived, of the increase of the specific heat of perfect gases with rise of temperature, has since been confirmed by the experiments of Messrs. Berthelot and Violle. For the law of increase between 0° and 3,000°, they give with reserve the formula

$$C = 4 \cdot 8 + 0 \cdot 0006\, t.$$

Temperatures of Combustion at constant pressure.—These are calculated from the temperatures at constant volume, by diminishing the constants for the specific heats at constant volume by 1·96. The value for H^2 and O is 3,200°, H_2 burning with air 2,000°, CO burning with air 2,115° with probable dissociation, CH^4 also with air 1,860°.

The Authors complete their memoir with certain theoretical considerations, mainly intended to show that it is inexact to assume that the energy of a given gaseous mixture, or of a gaseous molecule, is simply the product of its specific heat into its absolute temperature, and that Bunsen, after having determined for the first time with some approximation a temperature of combustion, was led to attribute to dissociation a phenomenon which for the greater part was due to an increase in the specific heat of gases with temperature.

E. F. B.

A simple means of Determining, within required Limits, the Amount of Carbonic Acid in Illuminating Gas.

By Dr. R. Blochmann.

(Journal für Gasbeleuchtung und Wasserversorgung, 10 August, 1884.)

Crude coal-gas contains about 4 per cent. of carbonic acid, the greater part of which can be removed by purification, and, if properly treated, it is easy to reduce the maximum to 1 per cent. in the purified gas. The determination of the carbonic acid may be effected with great accuracy, but most of the methods of analysis require special chemical knowledge, complicated appa-

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ratus, and much time, and they are consequently only applied occasionally in practice. The plan now proposed is so simple that it may be carried out by any intelligent workman in a few minutes. A known volume of the gas to be tested is shaken up with sufficient lime-water of a known composition, to combine with all the carbonic acid present, and, from the quantity of lime-water required, the volume of carbonic acid can be ascertained by a simple calculation. To determine the quantity of lime-water required, a few drops of a solution of phenolphtaline, in dilute alcohol, are added to the lime-water until it becomes distinctly red; the lime-water is then shaken up violently with the gas, and the carbonic acid is absorbed. When the combination is complete, if carbonic acid still exists in the gas, the liquid is completely discoloured, but a further addition of lime-water will restore the colour, which will again disappear by shaking, so long as any free carbonic acid is present. In this manner two limits may be found, between which the quantity required to exactly neutralize the carbonic acid lies, and according to the quantity of lime-water added each time, these limits may be reduced.

Lime-water is a test that may be easily produced at any time; 1 cubic centimetre of water absorbs, at the average temperature of 17·5° Centigrade (63½° Fahrenheit) 1·276 milligram of lime (Ca O), and as 56 parts of lime combine with 44 parts of carbonic acid—

$$1 \text{ cubic centimetre of lime-water} = \frac{1 \cdot 276 \times 44}{56} = 1 \cdot 0 \text{ milligram},$$

or 0·55 cubic centimetre of carbonic acid. If, therefore, 1 cubic centimetre of lime-water exactly suffices to neutralize the carbonic acid in 100 cubic centimetres of gas, then it would contain 0·55 per cent. of carbonic acid; or, if the gas contains 0·5 per cent. of carbonic acid, a cubic centimetre of lime-water would require—

$$\frac{100 \times 0 \cdot 55}{0 \cdot 5} = 110 \text{ cubic centimetres of gas.}$$

It will be seen from this, that if the divisions of the glass in which the lime-water is measured are to the volume of gas to be tested as 1 : 110, each division of lime-water employed will represent 0·5 per cent. of carbonic acid. For the test it is best to use a flask which will hold ½ litre of gas, and calculate from its contents the quantity of lime-water that will be required, which is to be measured in a burette graduated to represent 1 per cent., 0·5 per cent., 0·25 per cent., and so on, of carbonic acid. The use of the apparatus is extremely simple. A glass tube is bent at right angles; one end is inserted in the flask, and the other connected with the gas-supply; the flask is filled by being held upside-down; the tube is slowly withdrawn, and the flask quickly closed with a cork. If it is then wished to determine whether the gas contains more or less than 1 per cent. of carbonic acid, the burette is filled with lime-water up to the mark for 1 per cent., three

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drops of phenolphtaline solution are added, and the contents of the burette poured into the flask by slightly removing the cork and quickly replacing it. It is then vigorously shaken for about three minutes, and if the lime-water still remains red, the gas contains less than 1 per cent. of carbonic acid; but if it becomes colourless, it contains more: in the latter case, if it is required to ascertain the quantity of carbonic acid more accurately, a further portion of lime-water is added, and the flask again shaken: the limits can of course be reduced, according to the quantity of lime-water added each time. The temperature, barometric pressure, and the reduction in volume caused by the introduction of the lime-water, may be disregarded, as, with a variation of 5° Centigrade in temperature, and 2 millimetres in the barometer, the difference would not amount to more than 0·1 per cent. It is, however, to be observed that, if the gas contains sulphuretted hydrogen, the percentage of carbonic acid would appear to be increased.

C. G.

The Expansion of Liquids. By D. MENDELEEF.

(Annales de Chimie et de Physique, 6th series, vol. ii., 1884, p. 271.)

The Author reproduces a Table of the expansion of forty-seven liquids, as given by Mr. Thorpe in the "Journal of the Chemical Society," 1880, pp. 114, 327, classing them according to the percentage of their expansion, to indicate the regularity and uniformity of the expansion of liquids of the most different kinds. He then compares the expansion of mercury with that of bromide of phosphorus, and nitrogen tetroxide, and shows that, although the former expands 4·7 times, and the latter 8·7 times, as much as mercury, for an equal elevation of temperature, the expansion is perfectly uniform, and may be represented by the same formula,

$$v = \left(1 + \frac{k}{n} t\right)^n$$

as that for the expansion of gases; for gases $n = +1$, and for liquids $n = -1$; so that for liquids the formula takes the form

$$v = \frac{1}{1 - k t}.$$

The densities being inversely proportional to the volumes

$$D = D_0 - k D_0 t,$$

in which D and D_0 are the densities at a given temperature, and at zero respectively, the formula showing that the change of density with temperature is constant, and equal to $- K D_0$.

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Giving a numerical value to k, the Author finds that the formula agrees in all cases with the results of experiments within 1 per cent., which he discovers is the rate of error of experimentalists among themselves, and of the various results of the same individuals.

In the same manner as the expression $v = 1 + a\,t$ corresponds to the expansion of ideal gas, but is only approximate for any real gas, is it in the case of the formula $v = (1 - k\,t)^{-1}$ for liquids, and as the coefficient of expansion of gases which expand like liquids changes near the temperature of condensation, so it is with liquids near the boiling-point. The coefficient k increases not only at the temperature of the change of state of the liquid, but also with diminution of its density, its molecular weight, its temperature of boiling, and cohesion. The coefficient k may be called the modulus of expansion; thus, knowing the densities D and D_1, at temperatures t and t_1, $k = \dfrac{D - D_1}{D\,t_1 - D_1\,t}$, or the volumes v and v_1 at t and t_1, the modulus of expansion $k = \dfrac{v_1 - v}{t_1\,v_1 - t\,v}$.

E. F. B.

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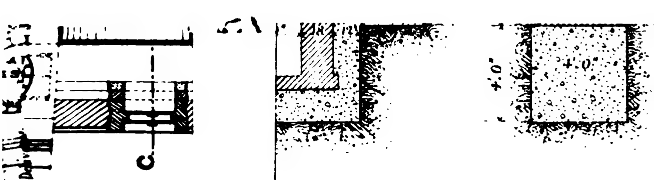

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